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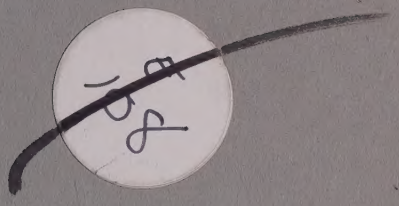

INSTRUCTION MANUAL

MODEL 602

SOLID STATE
ELECTROMETER

KEITHLEY INSTRUMENTS

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay domestic surface freight costs.

To exercise this warranty, call your local field representative or the Cleveland factory, DDD 216-248-0400. You will be given assistance and shipping instructions.

REPAIRS AND RECALIBRATION

Keithley Instruments maintains a complete repair service and standards laboratory in Cleveland, and has an authorized field repair facility in Los Angeles and in all countries outside the United States having Keithley field representatives.

To insure prompt repair or recalibration service, please contact your local field representative or the plant directly before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

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SPECIFICATIONS

AS A VOLTMETER:

RANGE: .001 volt full scale to 10 volts in nine 1x and 3x ranges.

ACCURACY: ±1% of full scale on all ranges exclusive of noise and drift.

ZERO DRIFT: Less than 1 millivolt per 24 hours, less than 150 microvolts per °C after 30-minute warm-up.

METER NOISE: ±25 microvolts maximum with input shorted on most sensitive range.

INPUT IMPEDANCE: Greater than 10^{14} ohms shunted by 20 picofarads. Input resistance may also be selected in decade steps from 10 to 10^{11} ohms.

AS AN AMMETER:

RANGE: 10^{-14} ampere full scale to 0.3 ampere in twenty-eight 1x and 3x ranges.

ACCURACY: ±2% of full scale on 0.3 to 10^{-11} ampere ranges using the smallest available multiplier setting; ±4% of full scale on 3×10^{-12} to 10^{-14} ampere ranges.

METER NOISE: Less than $\pm 3 \times 10^{-15}$ ampere.

OFFSET CURRENT: Less than 5×10^{-15} ampere.

AS AN OHMMETER:

RANGE: 100 ohms full scale to 10^{13} ohms in twenty-three linear 1x and 3x ranges.

ACCURACY: ±3% of full scale on 100 to 10^{9} ohm ranges using the largest available multiplier setting; ±5% of full scale on 3×10^{9} to 10^{13} ohm ranges.

AS A COULOMBMETER:

RANGE: 10^{-13} coulomb full scale to 10^{-6} coulomb in fifteen 1x and 3x ranges.

ACCURACY: ±5% of full scale on all ranges. Drift due to offset current does not exceed 5×10^{-15} coulomb per second.

AS AN AMPLIFIER:

INPUT IMPEDANCE: Greater than 10^{14} ohms shunted by 20 picofarads. Input resistance may also be selected in decade steps from 10 to 10^{11} ohms.

OUTPUTS: Unity-gain output and either voltage or current recorder output.

UNITY-GAIN OUTPUT: At dc, output is equal to input within 10 ppm, exclusive of noise and drift, for output currents of 100 microamperes or less. Up to one milliampere may be drawn for input voltages of 10 volts or less. Output polarity is same as input polarity.

VOLTAGE RECORDER OUTPUT: ±1 volt for full-scale input. Internal resistance is 910 ohms. Output polarity is opposite input polarity.

Gain: 0.1, 0.33, etc., to 1000.

Frequency Response (within 3 db): dc to 40 kHz at a gain of 1 and lower, decreasing to dc to 100 Hz at maximum gain. Full output response limited to 3 kHz on any gain.

Noise: Less than 3% rms of full scale at gain of 1000, decreasing to less than 0.5% at gains below 10.

CURRENT RECORDER OUTPUT: ±1 milliampere for full-scale input, variable ±5% with 1400-ohm recorders.

GENERAL:

ISOLATION: Circuit ground to chassis ground: Greater than 10^{10} ohms shunted by .0015 microfarad. Circuit ground may be floated up to ±1500 volts with respect to chassis ground.

POLARITY: Meter switch selects left-zero (positive or negative) or center-zero scales. Meter switch does not reverse polarity of outputs.

CONNECTORS: Input: Teflon-insulated triaxial Dage 33050-1. Low: Binding post. Voltage or current output: Amphenol 80-PC2F. Unity-gain output, chassis ground: Binding posts.

BATTERY CHECK: Condition of all batteries may be checked with front panel controls.

BATTERIES: Six 2N6 (or 246, VS305, NEDA 1602); one RM-1W. 1000 hours battery life.

DIMENSIONS, WEIGHT: 10½" high x 6⅝" wide x 10" deep; net weight, 13 pounds.

ACCESSORIES SUPPLIED: Model 6011 Input Cable: 30" triaxial cable with triaxial connector and 3 alligator clips. Mating output connector.

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL.

a. The Keithley Model 602 Electrometer is a completely solid-state battery operated instrument which measures a wide range of dc voltage, current, resistance and charge. The Electrometer's input resistance of greater than 10^{14} ohms is the result of extensive instrument development with high input impedance transistors. The Model 602 has all the capabilitites of conventional VTVMs, but it can also make many more measurements without loading circuits.

b. The Electrometer has nine voltage ranges from 0.001 volt full scale to 10 volts, twenty-eight current ranges from 10^{-14} ampere full scale to 0.3 ampere, twenty-three linear resistance ranges from 100 ohms full scale to 10^{13} ohms, and fifteen charge ranges from 10^{-13} coulomb full scale to 10^{-6} coulomb.

c. The Model 602 offers complete line isolation and excellent off-ground measuring capability. Up to 1500 volts may be applied between the input low terminal and the case, and safe operation is assured with the case grounded. A triaxial connector allows complete guarding of the high impedance input terminal.

d. The Model 602 employs matched insulated-gate field-effect transistors followed by transistor differential amplifier stages and a complimentary-output stage. A large amount of negative feedback is used for stability and accuracy.

1-2. FEATURES.

a. An important feature of the Model 602 is its excellent zero stability which permits accurate measurements with a minimum of adjustment. Short-term zero drift is less than 50 μV per hour. Zero offset due to temperature change is less than 150 microvolts per °C, after a 30-minute warm-up. This offset, however, can easily be compensated for with the front-panel zero controls.

b. Fast warm up is an inherent characteristic of this Electrometer. It can be used well within 30 minutes of a cold start on the most sensitive range and almost immediately on less sensitive ranges.

c. Low offset current — 5 x 10^{-15} ampere — minimizes zero offset with high source resistances and permits maximum resolution when measuring current and charge.

d. The 1000-hour life of the batteries enables usage in long-term experiments without interruptions for recharging. Battery life is maintained even when the 1-milliampere recorder output is used. For further convenience, battery condition is readily checked on the panel meter.

e. Excellent overload protection without degradation of performance is obtained by use of a unique input circuit. The Model 602 Electrometer will withstand overloads up to 500 volts on most ranges without damage and has good recovery.

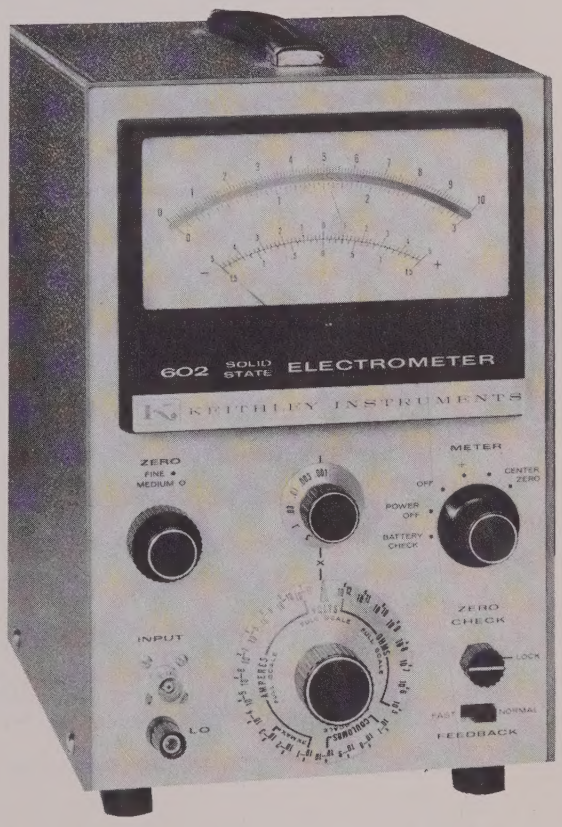


TABLE 1-1.
Front Panel Controls.

Control	Functional Description
Range Switch	Selects the mode which is to be measured: voltage, current, resistance or charge.
Multiplier Switch	Determines full-scale voltage sensitivity and can be used to multiply current, resistance and charge ranges on the Range Switch.
METER Switch	Checks battery condition; turns instrument off; disconnects meter; selects meter polarity; sets instrument for center zero operation.
ZERO Controls	Allows precise meter zeroing
ZERO CHECK Button	Zeroes meter on any range
FEEDBACK Switch	Determines the feedback connections within the instrument.
INPUT Receptacle	Connects input to source. Receptacle is a Teflon-insulated triaxial connector.
LO Terminal	Provides connection to input low.

TABLE 1-2.
Rear Panel Controls.

Control	Functional Description
COARSE ZERO Switch	Extends the zeroing capability of the front panel ZERO Controls.
OUTPUT Switch	Selects the Model 602 output: 1 milliampere or 1 volt. Must be in 1V Position if the output is connected to a load of more than 2 kΩ.
1 MA CAL Control	Varies the output from 0.95 to 1.05 mA.
OUTPUT Receptacle	Connects output to monitoring device.
X1 OUTPUT and OHMS GUARD Terminals	For guarded measurements and for use as an extremely linear preamplifier.
LO Terminal	Provides an alternate connection to input low.
CASE GROUND Terminal	Connects to Model 602 cabinet and outside shell of input connector.

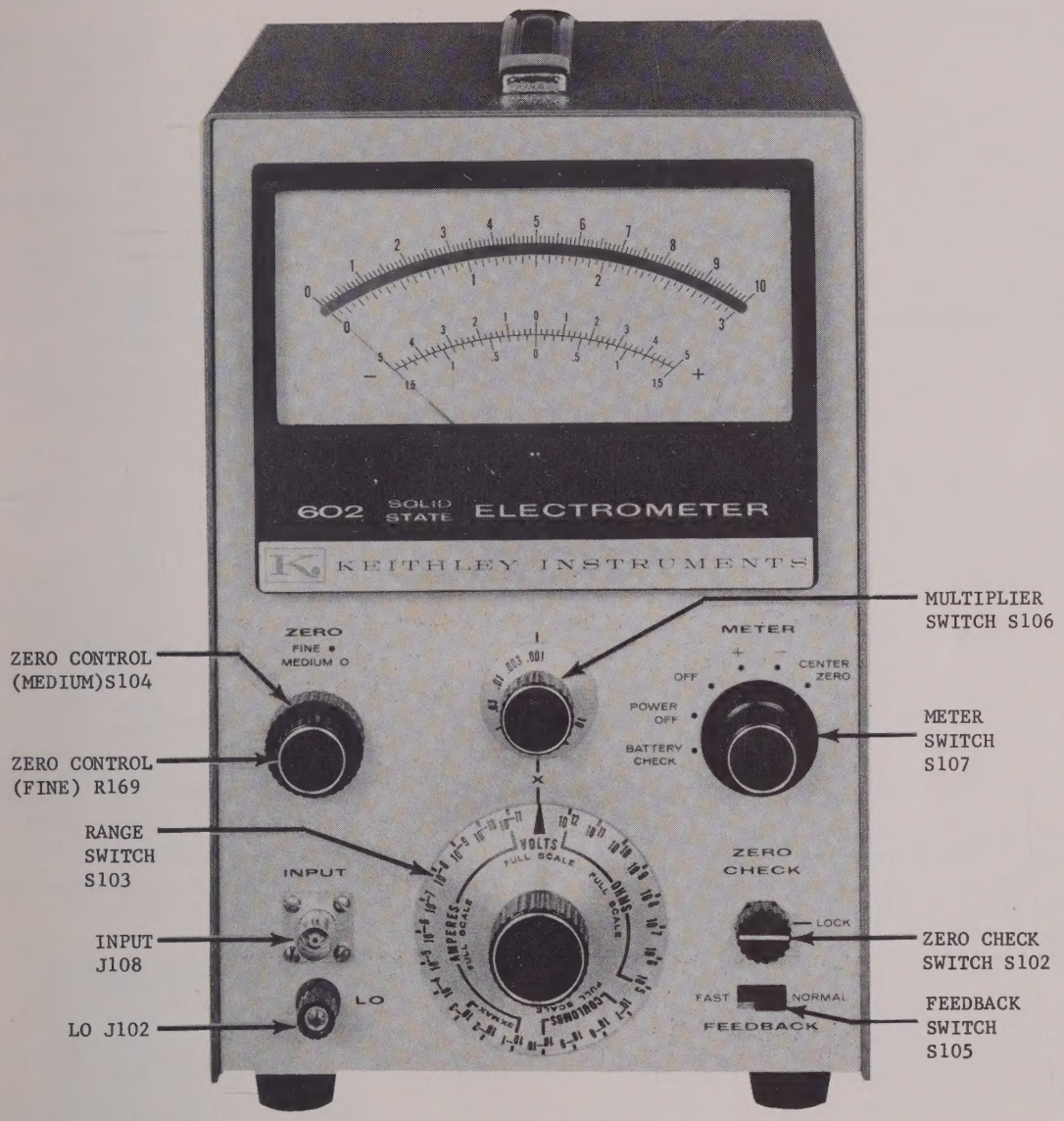


FIGURE 2. Front Panel Controls.

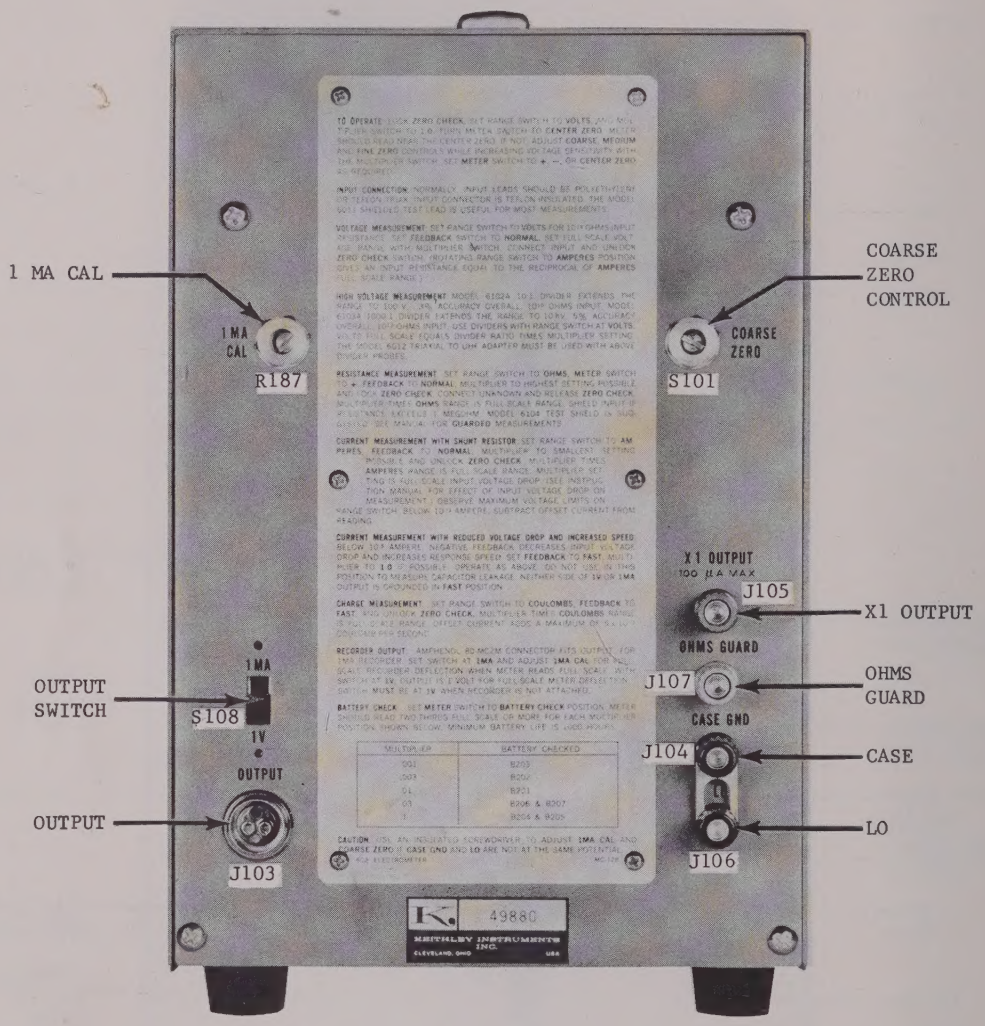


FIGURE 3. Rear Panel Controls.

SECTION 2. OPERATION

2-1. INPUT CONNECTIONS.

a. The Model 602 INPUT Receptacle is a Teflon-insulated triaxial connector. The center terminal is the high impedance terminal; the inner shield is the low impedance terminal: the outer shield is case ground. (See Figure 4 below.) A shield cap is provided. The LO Terminal, below the Receptacle, is connected to the inner shield; it is connected to case ground only if the shorting link on the rear panel is connected.

b. The accessories described in Section 4 are designed to increase the accuracy and convenience of input connections. Use them to gain the maximum capability of the Model 602.

TABLE 2-1. Color Coding of Alligator Clips for Model 6011 Input Cable.

Lead	Circuit	J101 Terminal
heavy wire with red clip cover	Input high	Center
thin wire with black clip cover	Input low	Inner
thin wire with green clip cover	Case	Outer Shield

c. The Model 6011 Input Cable, supplied with the instrument, facilitates input connections. Table 2-1 indicates the color coding of the alligator clips. The high impedance terminal is shielded by the inner braid of the triaxial cable up to the miniature alligator clip. If the unshielded clip causes pickup from nearby electric fields, remove it and connect the shielded lead directly to the source.

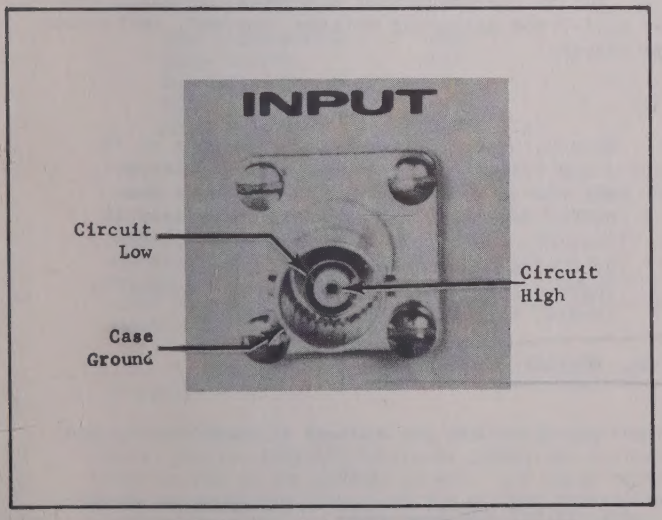


FIGURE 4. Triaxial Input.

d. When working with a high impedance source carefully shield the input connection and the source since any variation in the electrostatic field near the input will cause definite meter disturbances.

e. Use high resistance, low-loss materials — such as Teflon (recommended), polyethylene or polystyrene — for insulation. The insulation leakage resistance of test fixtures and leads should be several orders of magnitude higher than the internal resistance of the source. Excessive leakage reduces the accuracy of reading from high impedance sources. Triaxial or coaxial cables used should be a low noise type which employ a graphite or other conductive coating between the dielectric and the surrounding shield braid. Amphenol-Borg Electronics Corporation, Microdot, Inc., and Simplex Wire and Cable Company make satisfactory types. Use of the supplied Model 6011 Input Cable insures good input connections.

f. When working with a high impedance source any change in the shunt capacitance of the input circuit will cause disturbances in the reading. Make the measuring setup as rigid as possible, and tie down connecting cables to prevent their movement. A continuous vibration may appear at the output as a sinusoidal signal, and other precautions may be necessary to isolate the instrument and connecting cable from the vibrations.

NOTE

Clean, dry connections and cables are very important to maintain the value of all insulation materials. Even the best insulation will be compromised by dust, dirt, solder flux, films of oil or water vapor. A good cleaning agent is methyl alcohol, which dissolves most common dirt without chemically attacking the insulation. Air dry the cables or connections after washing with alcohol or use dry nitrogen if available. Or, if it is available, Freon is an excellent cleaning agent.

g. For low impedance measurements — below 10^8 ohms or above 10^{-8} ampere — unshielded leads may be used.

h. When the Model 602 is used on the most sensitive current range with the FEEDBACK Switch at FAST, some insulators — such as Teflon — may produce random signals which show up as erratic meter deflections. Insulation used in the Model 602 is carefully selected to minimize these spurious signals.

i. If a well shielded chamber and a well made high impedance transfer switch is available it is advantageous to connect the Model 602 to the circuit only when a reading is being made. In some cases, the offset current can charge the external test circuitry. One example of this occurs when measuring a capacitor's leakage resistance by observing the decay of the terminal voltage. If the leakage current is less than the offset current (less than 5×10^{-15} ampere), there may be no decay of the terminal voltage when the Electrometer is left connected across the capacitor's terminals.

NOTE

Keep the shield cap on the INPUT Receptacle when the Electrometer is not in use.

j. The Model 6012 Triaxial to Coaxial Adapter enables using coaxial cables and accessories with the Model 602 by adapting the triaxial INPUT connector to the UHF coaxial type.

CAUTION

The Adapter connects circuit low to case ground. The Model 602 cannot be used off-ground when using the Adapter. The instrument cabinet will be at the same potential as the input low.

2-2. PRELIMINARY PROCEDURES.

a. Check battery condition by holding the METER Switch in the BATTERY CHECK position. Rotate the Multiplier Switch through the .001 to 0.1 positions, and observe the meter readings. The meter should read two-thirds of full scale or more in each Multiplier Switch position. Table 2-2 shows the batteries checked by position. If the reading for any battery other than B203 is below two-thirds, replace all batteries except B203. If the reading for B203 is less than two-thirds full scale, replace it. Note that new batteries may cause the Model 602 to drift more than normal for at least 72 hours due to change in battery terminal voltage.

TABLE 2-2. Multiplier Switch Positions for Checking Conditions of Batteries.

Multiplier Position	Battery Checked
.001	B203
.003	B202
.01	B201
.03	B206 & B207
0.1	B204 & B205

b. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	VOLTS
Multiplier Switch	1
FEEDBACK Switch	NORMAL
METER Switch	POWER OFF.

c. Turn the METER Switch to CENTER ZERO. Within ten seconds, the meter needle should come to the center position. If not, adjust the meter zero with the MEDIUM and FINE ZERO Controls. Normally, there is no need to use the COARSE ZERO Switch.

NOTE

Using the center zero scales decreases accuracy 0.5% because the scale span is reduced.

d. After a few moments increase the voltage sensitivity by advancing the Multiplier Switch to .3, .1, etc. Continue zeroing with the FINE ZERO Control.

e. After long periods of storage or after an overload, the Model 602 may drift excessively. The input transistors are insensitive to mechanical shock; however, a severe input overload may cause a zero offset. This is corrected with the Zero Controls. Drifting, through, can occur for several hours.

NOTE

If the Model 602 has been stored for some time, the offset current will exceed the specification when first used, then decrease to below the specified amount after one or two hours of use. This is an inherent characteristic of the input transistors; the instrument is not faulty.

f. Although the offset current of the Electrometer is much below that found in conventional voltmeters, it can be observed on the meter. The current charges the input capacitance, and the Electrometer appears to drift when the input is open. Use the ZERO CHECK Button to discharge the charge build-up. Depressing the ZERO CHECK Button removes all signal from the amplifier and reduces the input impedance, the impedance between the Hi and Lo Terminals of the INPUT Receptalce, to 10 megohms.

g. Follow the particular procedures in paragraphs 2-3 to 2-7 for measuring voltage, current, resistance and charge.

NOTE

When using Multiplier Switch settings of 10, 3 and 1 in the voltage, current, resistance and charge measuring modes, make sure the OUTPUT Switch is set to 1V if the output is connected to a load of more than 2 kilohms. Otherwise, the meter will not read full-scale signals correctly. When the output is loaded, this effect is not present.

2-3. VOLTAGE MEASUREMENTS.

a. The Model 602 can be used to measure voltages

1. In the normal method — FEEDBACK Switch at NORMAL — the unknown voltage is connected to the INPUT Receptacle. Input impedance with the RANGE Switch in VOLTS Position is 10^{14} ohms, 20 pF.

2. To reduce the effects of input cable capacity, use the fast method — FEEDBACK Switch at FAST — and drive the inner shield of the Cable with the X1 OUTPUT which is connected to the LO Terminal in FAST Position, to measure the voltage. A guarded circuit is possible this way.

3. To reduce stray pickup when making routine measurements, i.e. measuring from low impedance sources, the range resistors or capacitors may be used to shunt the input.

4. Accessory probes extend the Model 602's range to 10 kilovolts.

NOTE

Locking the ZERO CHECK Switch places 10 megohms between input high and low, which may temporarily cause instability in some types of high impedance sources.

b. Normal Method Voltage Measurements.

1. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	VOLTS
Multiplier Switch	10
FEEDBACK Switch	NORMAL
METER Switch	CENTER ZERO

2. Connect the unknown voltage to the high and low terminals of the INPUT Receptacle; unlock the ZERO CHECK Button. Set the METER Switch to + for positive meter polarity or - for negative meter polarity, as necessary. Increase sensitivity with the Multiplier Switch. Recheck zero setting after increasing sensitivity.

3. For off-ground measurements, see paragraph 2-4.

c. Guard Method Voltage Measurements. This method reduces the effects of input cable capacity with very high impedance sources and allows guarded voltage measurements.

1. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	VOLTS
Multiplier Switch	10
FEEDBACK Switch	FAST
METER Switch	CENTER ZERO.

2. Connect the unknown voltage to the high (center) terminal of the INPUT Receptacle and to the OHMS GUARD Terminal on the rear panel. Use the LO Terminal as a guard between circuit high and low. Unlock the ZERO CHECK Button. Set the METER Switch to + or -, as necessary. Increase sensitivity with the Multiplier Switch. Recheck zero setting after increasing sensitivity.

3. To make off-ground voltage measurements, see paragraph 2-4.

d. Low Impedance Sources. To decrease input resistances, set the FEEDBACK Switch to NORMAL and the Range Switch to one of the AMPERES ranges. The input resistance is now the reciprocal of the current range. For instance, to obtain an input resistance of 10^7 ohms, set the Range Switch to the 10^{-7} AMPERES range. Set the full-scale voltage range with the Multiplier Switch. Operating procedures are the same as subparagraph b. With reduced input resistance, the Model 602 will not be deflected off scale by stray fields when the input is left open.

2-4. OFF GROUND VOLTAGE MEASUREMENTS.

a. The Model 602 can measure an unknown voltage whose low impedance terminal is up to 1500 volts off ground. Safe operation of the Electrometer is ensured by grounding the case of the Model 602. Its operation is the same as given in paragraph 2-3 except for some added cautions.

CAUTION

Operating the Model 602 more than 1500 volts off ground may permanently damage the instrument. Isolation between circuit low and ground may break down somewhere in the instrument. Since these breakdowns are very difficult to locate, it might not be possible to float the instrument safely again.

1. FEEDBACK Switch set to NORMAL. Disconnect the shorting link between the LO and CASE GROUND Terminals on the rear panel. Make sure the Model 602 case is securely connected to an earth ground, and that the low of the unknown voltage is less than 1500 volts off ground. Connect the unknown voltage directly to the INPUT Receptacle. Operate the Model 602 as described for normal method voltage measurements.

2. FEEDBACK Switch set to FAST. Disconnect the shorting link between the LO and CASE GROUND Terminals on the rear panel. Make sure the Model 602 case is securely connected to an earth ground, and that the low of the unknown voltage is less than 1500 volts off ground. Connect the high of the unknown voltage to the center terminal of the INPUT Receptacle. Connect the low to the OHMS GUARD Terminal. Use the LO Terminal or inner shield of the INPUT Receptacle as a guard. Operate the Model 602 as described for fast method voltage measurements.

WARNING

If the output is used for recording when the Model 602 is off ground in the normal or fast mode, make sure the shell of a mating plug to the OUTPUT Receptacle is not connected to either pin in the Receptacle. Also, the recorder output will be off ground.

WARNING

Use only an insulated blade screwdriver to adjust the COARSE ZERO Switch and 1 MA CAL Control when floating the Model 602. An ordinary screwdriver could short the circuit low to case ground, creating a shock hazard and damaging the external circuitry.

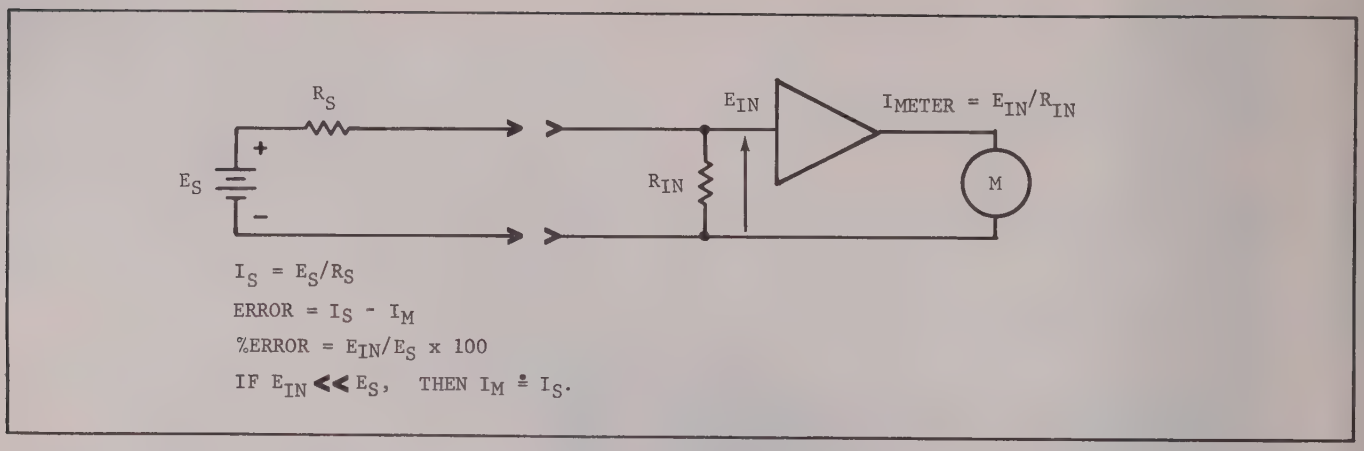


FIGURE 5. Error Due to Ammeter Resistance. Current sources may be considered a voltage (E) in series with a resistance (R). The current with the ammeter short circuited is I = E/R. With the short removed, the effective input resistance of the ammeter (R_{in}) is in series with the source resistance (R).

2-5. CURRENT MEASUREMENTS.

a. The Model 602 can measure current three ways.

1. In the normal method — useable on any range — the current is determined by measuring the voltage drop across a resistor shunting the amplifier input. This method is useful when low noise is more important than fast response speed or if some damping is needed.

2. In the fast method — for use only below the 10^{-5} ampere range — the shunt resistor is between the amplifier output and input in the feedback loop. This circuit largely neutralizes the effect of input capacity and greatly increases the response speed. Also, the input voltage drop is reduced to a maximum of one millivolt on any range.

3. For galvanometric current measurements, the Model 602 acts as a null indicator between a known current and the unknown current source.

b. Rise time varies primarily with the current range, the input capacity and the method used. With the FEEDBACK Switch in the FAST position, the rise time on the most sensitive range is less than 2 seconds, and on the 10^{-6} ampere range, less than 3 milliseconds. Given a choice, it is better to place the Electrometer nearer to the current source than to the data reading instrument. Transmitting the input signal through long cables slightly decreases the response speed and greatly increases noise due to cable capacitance.

c. To measure from a source with both terminals off ground in either method, remove the link between the LO and CASE GROUND Terminals on the rear panel. Connect the unknown current to the INPUT Receptacle. The source must be less than ±1500 volts off ground (see paragraph 2-4).

d. Normal Method (0.3 to 10^{-14} ampere ranges).

1. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	10^{-1} AMPERE
Multiplier Switch	1
FEEDBACK Switch	NORMAL
METER Switch	CENTER ZERO.

Connect the unknown current to the high terminal (center terminal) of the INPUT Receptacle and use the low terminal (inner shield) for the return path. Unlock the ZERO CHECK Button. Set the METER Switch to + or -, as necessary. Increase the sensitivity with the Range Switch and the Multiplier Switch. Do not set the Multiplier Switch higher than 3 for Range Switch settings 10^{-3} and above. Check zero with the ZERO CHECK Button.

2. The full-scale current range is Multiplier Switch setting times Range Switch setting. Use the smallest Multiplier Switch setting possible to minimize input voltage drop and thus obtain the best accuracy. The input resistor varies with the Range Switch setting, from 10 ohms to 10^{-1} AMPERES to 10^{11} ohms for 10^{-11} AMPERES. The full scale input voltage drop is equal to the Multiplier Switch setting.

e. Fast method (current below 10^{-5} ampere).

1. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	10^{-6} AMPERES
Multiplier Switch	1
FEEDBACK Switch	FAST
METER Switch	CENTER ZERO.

Connect the unknown source to the INPUT Receptacle and lock the ZERO CHECK Button. Set the METER Switch to + or -, as necessary. Increase the sensitivity with the Range Switch and the Multiplier Switch. Check zero only with the ZERO CHECK Button. Do not short the input, because this will remove the feed-

back from the circuit.

2. The full-scale current range is the Multiplier Switch setting times the Range Switch setting. When selecting the Multiplier Switch setting, remember smaller settings permit lower source resistances, and larger settings improve instrument zero stability. Check the caution in subparagraph 3a below.

3. With the fast method, the input drop is reduced and the response speed is increased at least 100 times. However, observe these precautions.

a) The internal impedance of the unknown current source should not be less than 0.1 of the value of the feedback resistor being used. Otherwise, adequate feedback voltage cannot be developed at the input, and zero instability results. The feedback resistor value is the reciprocal of the AMPERES range of the Range Switch.

b) The low side (Pin No. 2) of the OUTPUT Receptacle is no longer connected to the low side of the INPUT Receptacle. Therefore, do not use a grounded recorder. As an alternative use the unity-gain output. (See paragraph 2-9).

c) Use, with caution, the fast method to measure capacitor leakage. A very stable voltage supply must be used. Connecting a capacitor to the input changes the circuit to a differentiator, resulting in extreme sensitivity to very small voltage transients and an increase in meter noise.

f. Galvanometric Method.

1. Operate the Model 602 as a picoammeter in the fast method. Use an accurate reference current source such as the Keithley Model 261 to buck out the unknown current source. Connect as shown in Figure 6.

2. Set the METER Switch to CENTER ZERO and use the higher current ranges. Adjust the buckout current to indicate null on the Model 602. Increase the Electrometer sensitivity as needed. When the Model 602 is as close to null as possible, the unknown current is equal to the algebraic sum of the Model 261 setting and the Model 602 current reading.

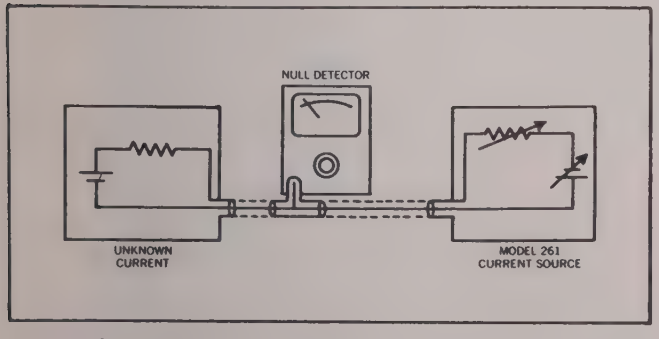


FIGURE 6. Measuring Current by the Galvanometric Method. Use an accurate reference current source to buck out the unknown current source. The Model 602, on its current ranges, serves as a null detector. Use a UHF-tee fitting and Model 6012 Adapter at the Model 602 input. Connect the Electrometer to the two sources with coaxial cable. Select cable carefully for very low currents (see paragraph 2-1).

2-6. RESISTANCE MEASUREMENTS.

a. The Model 602 can measure resistance by two methods.

1. In the constant current method, the Electrometer measures the voltage drop across the unknown sample as a known, constant current flows through it. The voltage drop is proportional to the resistance of the sample. In this method the Model 602 can be used in one of two different modes: normal or fast.

a) The normal mode is recommended for use from 100 to 10^{11} ohms.

b) Above 10^{11} ohms the fast method is preferred. It results in faster response speed and also nullifies leakage across the Electrometer input, since the potential across the input terminal is small.

2. In the preceding method, the voltage across the sample cannot be arbritrarily set. In some cases, as in measuring capacitor leakage, this results in excessively long testing time. In the voltmeter-ammeter method, the Model 602 is used as a picoammeter The unknown resistance sample is connected to an external known voltage source and the current through the sample is measured. Either the normal or fast method may be used. The resistance is calculated from the readings.

NOTE

Discharge any capacitor completely before removing it from the circuit. Depressing the ZERO CHECK Button shorts the input through a 10-megohm resistor, providing a discharge path.

b. Normal Constant Current Method (recommended for use from 100 to 10^{11} ohms).

1. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	10^{12} OHMS
Multiplier Switch	1
FEEDBACK Switch	NORMAL
METER Switch	+

Connect the high impedance side of the resistance sample to the high terminal (center terminal) of the INPUT Receptacle and the low impedance side to the low terminal (inner shield) of the INPUT Receptacle. Unlock the ZERO CHECK Button. Check zero only with the ZERO CHECK Button.

NOTE

Do not open circuit the Electrometer on the OHMS ranges; the input will develop up to 10 volts due to its constant current characteristic. Keep the input shorted or the ZERO CHECK Button locked.

2. The full scale ohms range is the Multiplier Switch times the Range Switch setting. Use the smallest Range Switch setting possible to obtain the best accuracy.

3. Before making a final reading, manipulate the Multiplier and Range Switches, so the sample is tested at a number of test potentials. The applied test voltage is the percentage of full scale that the meter reads times the Multiplier Switch setting.

4. When the test current is applied, the high terminal of the INPUT Receptacle is positive. The test current is the reciprocal of the OHMS Range setting.

NOTE

Shield the input if the resistance sample exceeds 10^8 ohms.

c. Fast Constant Current Method (recommended for use from 10^{11} to 10^{14} ohms).

1. Follow the instructions of paragraph 2-2. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	10^{11} OHMS
Multiplier Switch	1
FEEDBACK Switch	FAST
METER Switch	+

Connect the high impedance side of the resistance sample to the center terminal of the INPUT Receptacle and the low impedance side to the OHMS GUARD Terminal. Unlock the ZERO CHECK Button.

2. Read the resistance as in subparagraph b2 above.

3. The low terminal of the INPUT Receptacle is now a driven guard. It may be used to minimize the effects of capacity between high and low and errors due to leakage resistance between high and low.

4. The Model 6011 Input Cable, supplied with the Model 602, provides a convenient means of making guarded resistance measurements. Connect the shorting link between the CASE GROUND and OHMS GUARD Terminals on the rear panel. This allows the CASE GROUND or blue test lead terminal to be connected to the low impedance side of the unknown resistance. The inner shield or the black test clip is the OHMS GUARD Terminal.

d. Voltmeter-Ammeter Method (to 10^{16} ohms).

1. Turn the ZERO CHECK Switch to LOCK. Connect sample between High Terminal of the INPUT Receptacle and power supply. (See Figure 7) Put a switch in the high voltage line to connect the low impedance end of sample to input low when it is disconnected from the potential.

2. If the power supply must be floating, remove the link between the CASE GROUND and LO Terminals and connect the CASE GROUND Terminal to an earth ground.

3. Set the FEEDBACK Switch to NORMAL. Usually this method is best, since instabilities can arise for resistance samples less than 0.1 the value of the feedback resistor.

4. To make a measurement, start with switch S as shown in Figure 7 and make sure the ZERO CHECK Button is set to LOCK. Set switch S to apply a potential across the sample for a known period of time. Then unlock the ZERO CHECK Button and take the reading. Set the Range Switch to 10^{-1} AMPERES and increase sensitivity until a reading is obtained.

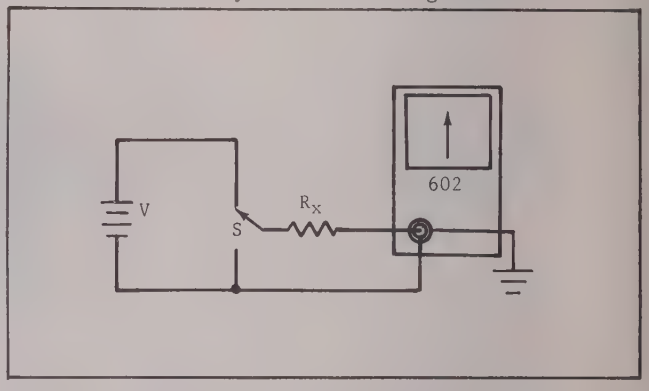


FIGURE 7. Measuring Resistance by the External Voltage Method. A potential from a known source, V, is applied to the unknown resistance sample, R_X. The Model 602 measures the current through R_X, from which the resistance is calculated. Switch S connects the low end of R_X to input low when no potential is applied.

5. To remove the sample, set the ZERO CHECK Button to LOCK and set switch S back to the position shown in Figure 7.

6. If the potential applied is at least 100 times the full-scale input drop (Multiplier Switch setting), the resistance is equal to the applied potential divided by the current reading. The high voltage sensitivity of the Model 602, therefore, permits external voltages of 0.1 volt or more to be used.

7. If the potential applied is less than 100 times the input drop, the resistance is equal to the difference between the applied potential and the input drop all divided by the current reading.

8. If the current is read by the fast method, the input drop is so slight that it need not be included in the calculation. If the capacity shunted across the sample is large, such as encountered in capacitor leakage measurements, the faster method increases response speed and this connection is recommended. Note, however, that power supply transients will be magnified.

2-7. CHARGE MEASUREMENTS.

a. Follow the instructions of paragraph 2-2. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	10^{-7} COULOMBS
Multiplier Switch	.01
FEEDBACK Switch	FAST
METER Switch	CENTER ZERO

Unlock the ZERO CHECK Button and then connect the unknown source to the INPUT Receptacle. If the Electrometer reads off scale, increase the Multiplier Switch setting. If the sensitivity is not enough, decrease the Multiplier Switch setting until the reading is on scale. Changing the Multiplier Switch setting does not affect the transfer of charge from the unknown source to the instrument. If increasing sensitivity with the Multiplier Switch does not bring the reading on scale, increase sensitivity with the Range Switch and repeat the above steps.

b. The full-scale charge range is the Range Switch setting times the Multiplier Switch setting. Input offset contributes a charge of 5×10^{-15} coulomb per second maximum.

c. Use the ZERO CHECK Button to discharge the integrating capacitor. Discharge for at least 20 seconds on the 10^{-7} coulomb range before making another measurement. On the 10^{-8} coulomb range, discharge for at least two seconds.

2-8. RECORDER OUTPUTS.

a. For recording with the Model 602, use the Keithley Model 370 Recorder for ease, economy, versatility and performance. The Model 370 is a pen recorder with 10 chart speeds and 1% linearity. It can float up to ±500 volts off ground. The Model 370's input cable has a connector which mates directly with the OUTPUT Connector on the Model 602; this avoids interface problems often encountered between a measuring instrument and a recorder. The Model 602 output, when set to the 1 MA Position, will drive the 370; no preamplifier is needed. No special wiring is required. When using the Model 370 make sure the Recorder's sensitivity control is set to maximum (completely clockwise).

b. Other recorders, oscilloscopes and similar instruments can be used with the Model 602. The Model 602 has two outputs, ±1 volt and ±1 milliampere, to amplify signals within 1/2% for recorders, oscilloscopes and similar instruments. These can be used on all ranges of the Model 602.

WARNING

Neither terminal of the OUTPUT Receptacle will be at case ground potential if the 602 is used off ground. Make sure the shell of any mating plug is not connected to either terminal in the Receptacle. Use a recorder with an isolated input when making off-ground measurements.

c. 1-Volt Output. Connect oscilloscopes and pen recorder amplifiers to the OUTPUT Receptacle. Pin no. 1 is the output terminal and pin no. 2 is grounded when the FEEDBACK Switch is set to NORMAL. Set the OUTPUT Switch to 1 V. The Model 602 output is now ±1 volt for full-scale meter deflection on any range. Internal resistance is 910 ohms. The frequency response (±3 dB) is dc to 100 Hz at a gain of 1000, rising to 40 Hz at gains of 1.0 and below. Noise is less than 3% rms of full scale at a gain of 1000, decreasing to less than 0.5% at gains below 10. The METER Switch does not reverse the output polarity. Output polarity is opposite input signal polarity.

d. 1-Milliampere Output: Connect 1-milliampere instruments to the OUTPUT Receptacle. Pin no. 1 is the negative terminal (for positive inputs). Set the OUTPUT Switch to 1 MA. The output is approximately 1 milliampere for full-scale meter deflection on any range. For exact output, adjust the meter on the .003-volt range with the FINE ZERO Control for full-scale deflection. Then adjust the 1 MA CAL Control until the recorder reads full scale. Check the recorder and meter zero and repeat adjustment if necessary. The METER Switch does not reverse the output polarity. Use only insulated screwdriver to adjust the 1 MA CAL Control.

e. For servo rebalance recorders, use a divider of not greater than a total of 2 kilohms across the Model 602 OUTPUT Receptacle. See Figure 8. Set the OUTPUT Switch to 1 MA. Use the 1 MA CAL Control to trim the output for full-scale recorder deflection. Operation is the same as for current outputs.

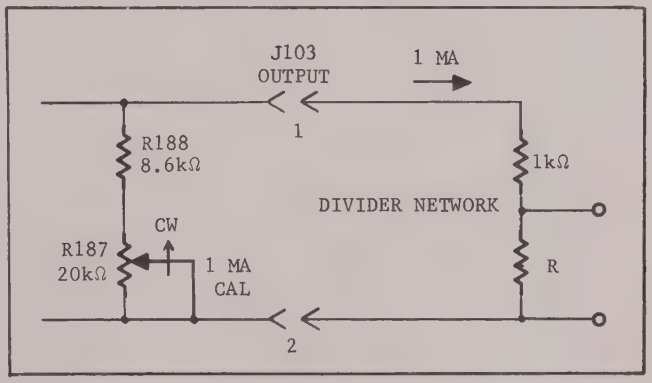


FIGURE 8. Divider Circuits Across Model 602 Output for Driving 50 and 100-Millivolt Recorders. Use 5% resistors in the dividers. The value of resistor R is one ohm for every 1 mV of output.

f. When the FEEDBACK Siwtch is in the NORMAL position, the negative side of the output terminal is connected to the LO Terminal. Therefore, no difficulty will be experienced using oscilloscopes and recorders with the Model 602 set for normal operation. In FAST position, however, neither output terminal is common to the LO Terminal. If this is used, make sure there is no common connection between the recorder or oscil-

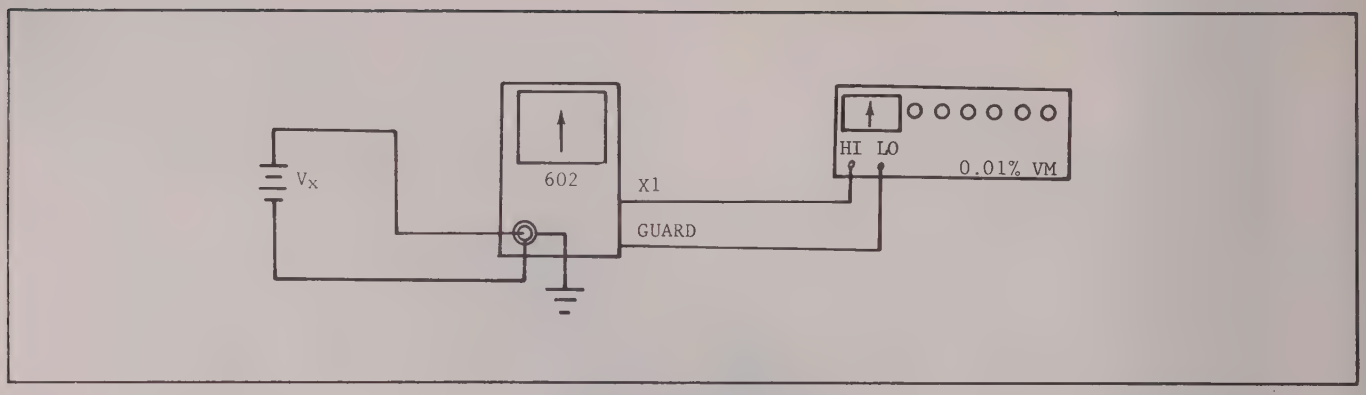


FIGURE 9. Measuring Potential of High Resistance Source with 0.025% Accuracy. The Model 602 is used between a high-resistance source, V_X, and a 0.01% voltmeter to obtain high accuracy without causing circuit loading. The digital voltmeter or, as above, the Keithley Model 662 Differential Voltmeter connects to the Model 602 unity-gain terminals.

loscope and the Model 602 LO Terminal, or use the unity-gain output.

2-9. UNITY GAIN OUTPUT. The unity-gain amplifier can be used as an impedance matching device to minimize circuit loading errors or for convenient connections to a recorder when the FEEDBACK Switch is in FAST position.

a. The unity-gain output is equal to the input within 10 ppm when the load resistance is 100 kilohms or greater. By placing the Model 602 between a 10^{10} ohm source, for example, and a 0.01% voltmeter with a 1-megohm input resistance, overall accuracy better than 0.025% can be achieved.

1. Connect the voltmeter to the X1 OUTPUT and GUARD Terminals as shown in Figure 9. The GUARD Terminal is connected to LO Terminal with the FEEDBACK Switch in NORMAL. Maximum output amplitude is ±10 volts.

2. Adjust the Model 602 Zero Controls to obtain a zero-voltage reading on the external voltmeter. Make sure the latter's sensitivity is high enough for a precise zero adjustment. This adjustment is necessary because a slight zero shift may occur when the Model 602 is changed from the 0.1-volt range or lower to a range above 0.1 volt. The shift, caused by a gain-reducing network switched in by the amplifier on the 1-volt and higher ranges, is too slight to be read on the meter, but it can cause an error in accurate measurements using the unity-gain output.

3. To avoid the shift use the Model 602 with the Multiplier Switch set to 10.

b. When the FEEDBACK Switch is in FAST position, the unity-gain terminals permit more convenient connections to oscilloscopes with a load resistance of greater than 100 kilohms without special precautions. In this mode, the X1 OUTPUT Terminal is common to the input low and the OHMS GUARD Terminal delivers an output equal to the input signal.

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL.

a. The Keithley Model 602 is basically an extremely stable and linear dc voltmeter with a full-scale sensitivity of 1 millivolt and an input impedance of 10^{14} ohms shunted by 20 picofarads. By using the front panel controls, shunt resistors and capacitors are selected to make measurements over a total of 75 voltage, current, resistance, and coulomb ranges. Current and resistance are measured using precision resistance standards, from 10 ohm wirewound resistors to 10^{11} ohm glass sealed, deposited carbon resistors. Coulombs are measured using close tolerance polystyrene film capacitor standards.

b. Batteries furnish the necessary amplifier power.

3-2. VOLTMETER OPERATION.

a. The Model 602 employs matched insulated-gate, field-effect transistors followed by a transistor differential amplifier with a high voltage complementary output stage. Figure 10 shows the block diagram for the voltmeter mode of operation.

b. Voltmeter operation of the Model 602 is as follows:

1. The amplifier is always in a unity-gain, input voltage to output current converter configuration. The internal circuitry is arranged such that a full scale input voltage (e_i) results in exactly a 1 milliampere output current, through the divider string composed of R_m, R167, and the meter. Voltage gain of the circuit is determined by the ratio of R167 to R_m. Output is taken across R167.

2. The voltage drop across the amplifier is

$$e_a = \frac{e_i}{K+1}$$

where K is the amplifier loop gain, greater than 10^6 on all ranges.

c. The complementary output stage, Q114 and Q115, drives the amplifier ground at the same potential as the input signal. Thus the input impedance is maintained for any value input voltage and the need for input dividers is eliminated. The amplifier ground is not chassis ground, but it connected directly to J105, the unity-gain output.

NOTE

Refer to Schematic Diagram 21174E for circuit designations.

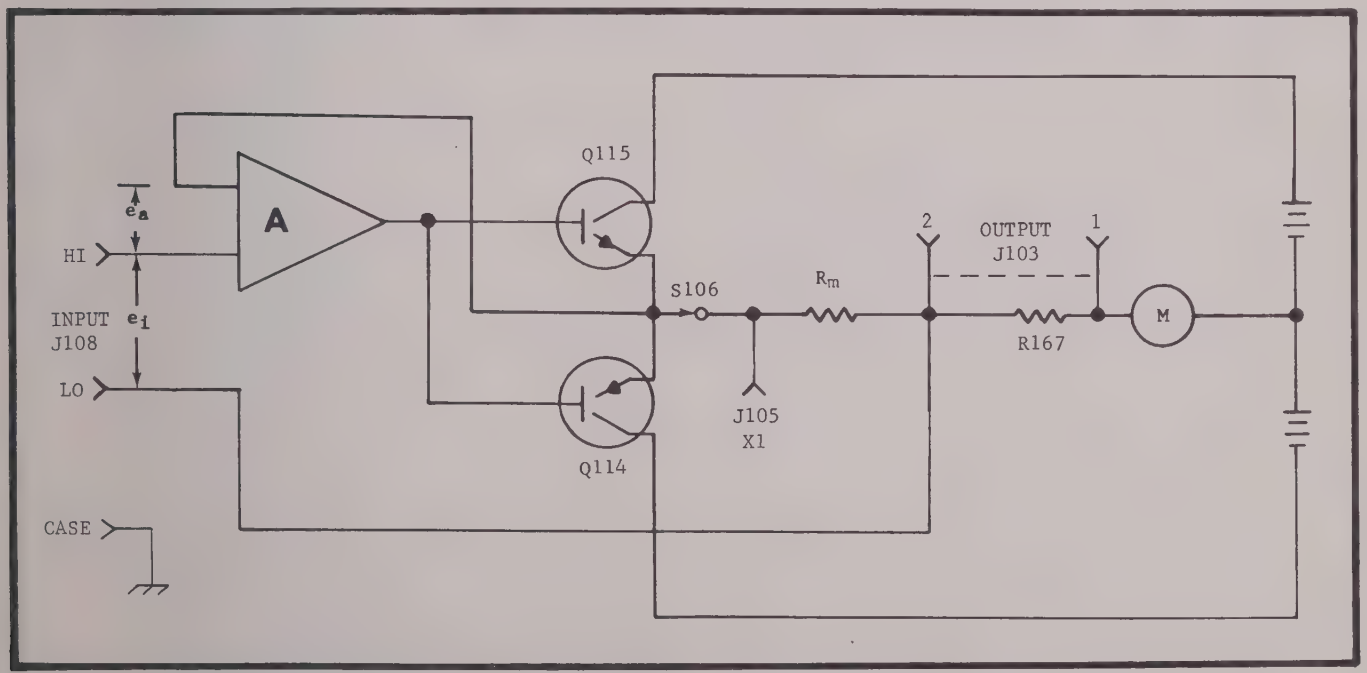


FIGURE 10. Block Diagram of Model 602 in Voltmeter Mode. Circuit designations refer to schematic diagram.

3-3. VOLTMETER CIRCUIT.

a. The amplifier input stage is a pair of insulated-gate, field-effect transistors, Q101 and Q102, in a differential configuration. The gate of Q102 is returned to amplifier common, the unity-gain output.

b. Depressing the ZERO CHECK Button, S103, places the gate of the active insulated gate devices at zero potential.

c. The input stage is followed by a transistor differential amplifier, composed of Q103-Q110. Q108 and Q109 make up the output gain stage, which is utilized in a gain-multiplier configuration. This stage provides the remainder of the high gain required by the amplifier. Also, this stage prevents fold-over and lock-up with positive input overloads. Diode D101, between base and emitter of Q110, prevents fold-over and lock-up under negative input overloads.

d. Frequency compensation is provided by capacitors C114, C115, resistors R145, R148, and capacitor C116. The compensation networks provide a controlled frequency characteristic to insure stability under all conditions of capacitive loading on input and output while on any range.

e. The recorder output is derived from the current flow from Q114 and Q115 through the divider, R_m, R167, and the meter. With the 1V-1MA Switch, S108, on 1V, ±1 volt for full-scale deflection is obtained at output connector, J103, by ±1.1 milliamperes flowing through the divider. With S108 at 1MA, R187 and R188 are connected across J103, allowing ±1 milliampere, ±5%, to pass through an external load.

3-4. AMMETER OPERATION.

a. Normal Method. In the normal method of current measurements (FEEDBACK Switch in NORMAL position), one of the Range Switch resistors, R102 through R112, shunts the input. (See Figure 11). The Model 602 then measures the voltage drop across the resistor. The meter is calibrated to read the current in amperes for the appropriate range.

b. Fast Method. In the fast method of current measurements (FEEDBACK Switch in FAST position), the Model 602 functions as an ammeter with negative feedback. The differential amplifier output is divided by the Multiplier Switch resistors, R156 to R164, and fed back to the amplifier input through a feedback resistor selected with the Range Switch. (See Figure 10). Floating ground is connected to the low impedance side of the input, and the output ground is floating. This method increases the response speed by minimizing the effects of input capacity; it also reduces the input drop to less than 1 millivolt.

3-5. OHMMETER OPERATION.

a. Normal Method. In the normal method of resistance measurements (FEEDBACK Switch in NORMAL position), the Model 602 uses a constant-current, voltage-drop circuit. Refer to Figure 12. R_x is the unknown resistor. A voltage source, E, applies a potential across R_x. The source is obtained from the batteries, B201 and B202, through the resistor divider network, R184, R142 and R143. E varies depending upon the OHMS

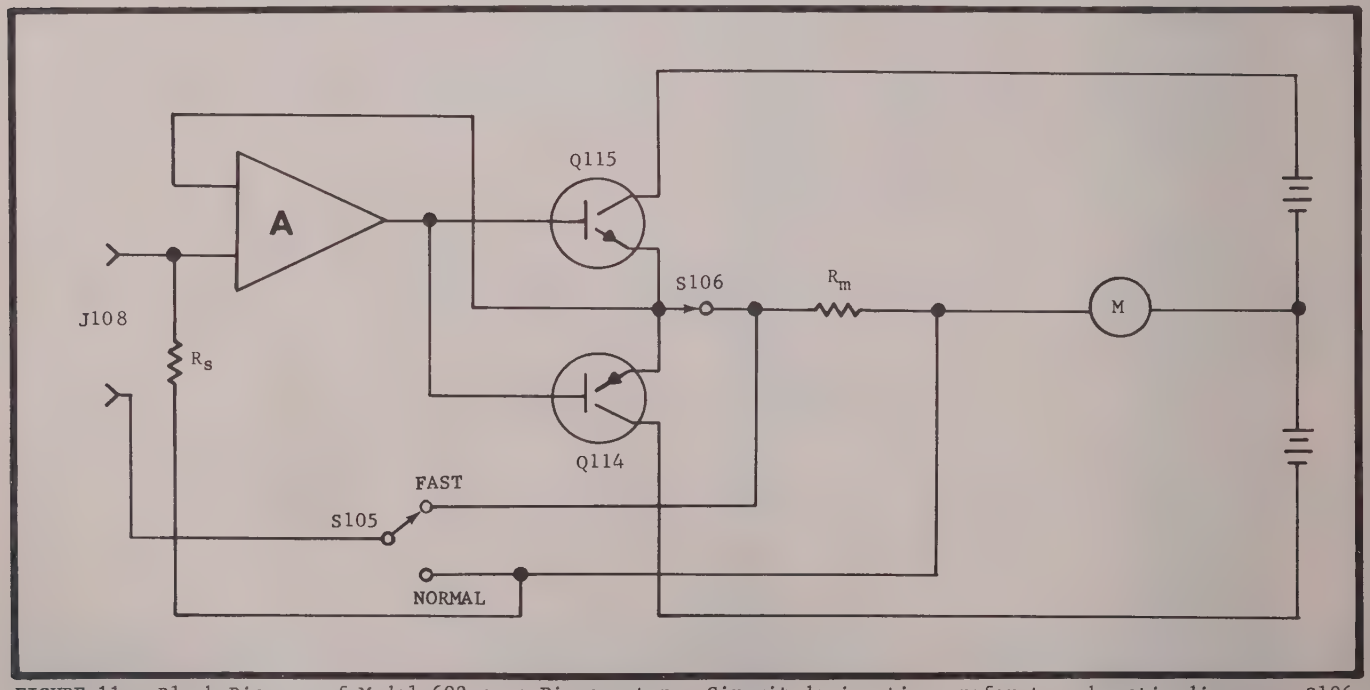


FIGURE 11. Block Diagram of Model 602 as a Picoammeter. Circuit designations refer to schematic diagram. S106 is the Multiplier Switch; R_m is the resistor for a given setting. R_s is the resistor selected by the Range Switch, S102. S105 is the FEEDBACK Switch.

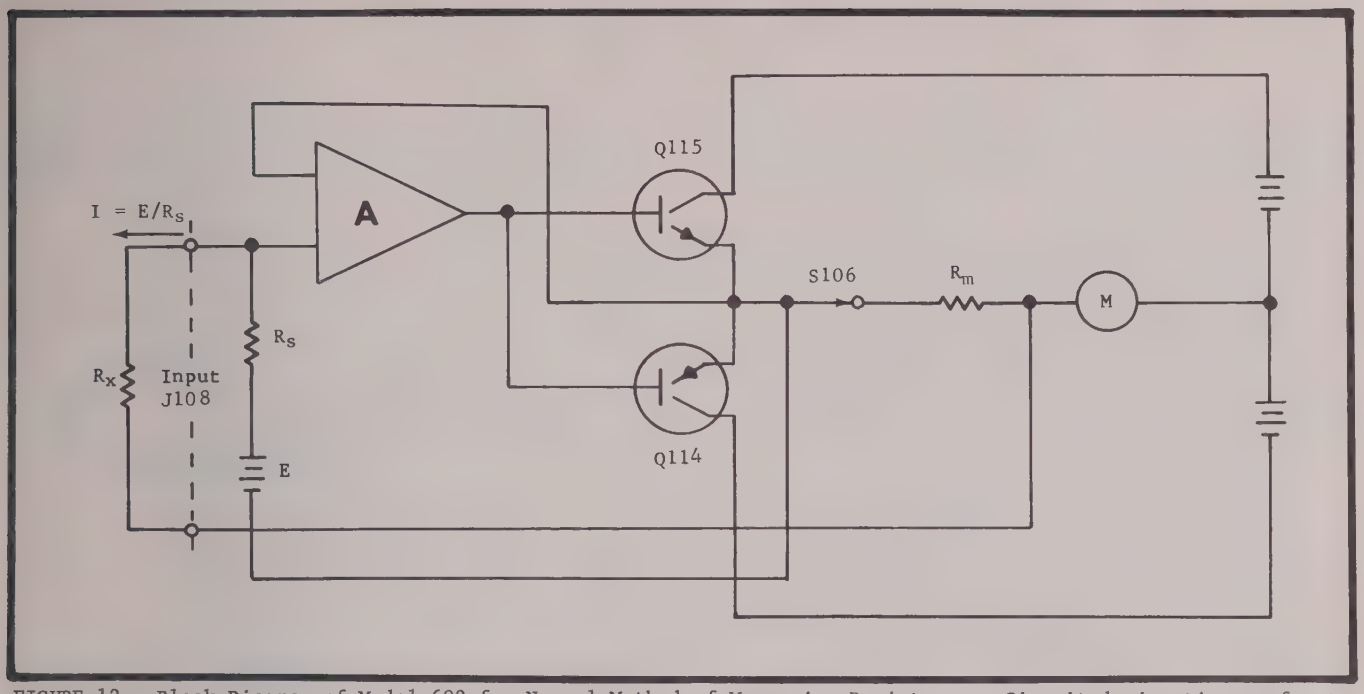


FIGURE 12. Block Diagram of Model 602 for Normal Method of Measuring Resistance. Circuit designations refer to schematic diagram. S106 is the Multiplier Switch; R_m is the resistor for a given setting. R_X is the unknown resistance being measured; E is the voltage source (see paragraph 3-5); R_S is the range resistor selected with the Range Switch.

range used. The voltage source is connected between floating ground and the input gate of Q101 through R_S, the range resistor. R_S is one of the resistors, R102 through R112. I is equal to E/R_S, regardless of the value of R_X, as long as the voltage drop across R_X does not exceed the Multiplier Switch setting. This circuit provides a true source regardless of the input. The Model 602 can then measure the voltage drop across R_X and indicate the resistance value on its calibrated meter.

b. Guarded Method. In the guarded method of resistance measurements (FEEDBACK Switch in FAST position and the sample resistance connected between the INPUT Terminal, J108, and the GUARD Terminal, J107), feedback is applied through the sample. Refer to Figure 11. The circuit is similar to the normal method, except for the feedback. This reduces the slowing effect of the instrument's input capacity. Leakage error is also reduced since the potential across the input terminal is small. In this mode, floating ground is connected to the low impedance side of the input and the output ground is floating. The GUARD Terminal is at output ground potential.

3-6. COULOMBMETER OPERATION. The Model 602 circuit for measuring charge is similar to that used for an ammeter with the fast method. A negative feedback is applied around a shunt capacitor, C108 to C111, selected with the Range Switch. The shunt capacitor replaces R_S in Figure 11. The stored charge is proportional to the voltage across the capacitor, which is measured by the Model 602 voltmeter circuits.

SECTION 4. ACCESSORIES

4-1. GENERAL. The following Keithley accessories can be used with the Model 602 to provide additional convenience and versatility.

4-2. OPERATING INSTRUCTIONS. A separate Instruction Manual is supplied with each accessory giving complete operating information.

Model 6101A Shielded Probe

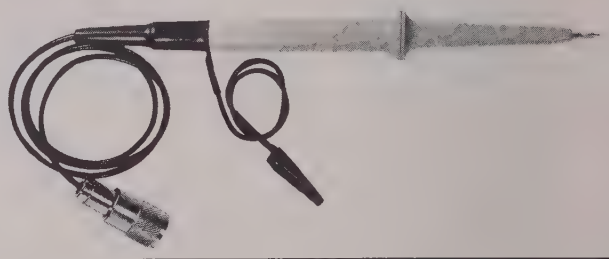
Description:

The Model 6101A is a shielded cable with a needle-point probe and 30 inches of low noise cable terminated by a UHF connector.

Model 6101B Shielded Probe

Description:

The Model 6101B is a shielded cable with a "gripping type" probe and 30 inches of low noise cable terminated by a UHF connector.



Model 6103A Divider Probe

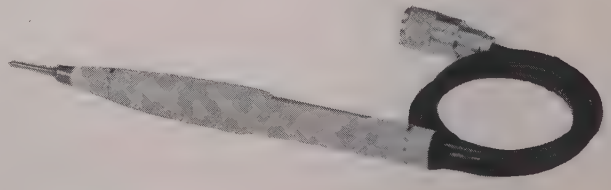
Description:

The Model 6103A is a shielded cable with a needle-point probe and 30 inches of low noise cable terminated by a UHF connector. The probe includes a 1000:1 voltage divider with a $10^{12}\Omega$ input resistance. Accuracy is $\pm 6\%$ at 30 kilovolts.

Model 6102A Divider Probe

Description:

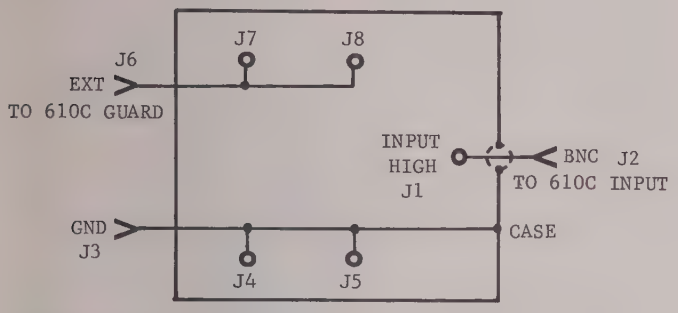
The Model 6102A is a shielded cable with a needle-point probe and 30 inches of low noise cable terminated by a UHF connector. The probe includes a 10:1 voltage divider with $10^{10}\Omega$ input resistance. Accuracy is $\pm 4\%$ at 1000 volts.



Model 6104 Test Shield

Description:

The Model 6104 is a shielded test box for two-terminal or three-terminal connections. The INPUT terminal is teflon insulated.



Applications:

1. Two Terminal Connections. Resistance measurements can be made conveniently using the INPUT and GROUND terminals on the Test Box. Connect the electrometer to the BNC output. Use the electrometer in NORMAL mode for ohms measurement.

2. Three Terminal Connections. The GUARD output on the Model 602 electrometer can be used for resistance measurements where the effects of cable capacitance may be significant. Connect the unknown between INPUT and EXT terminals. Connect the EXT terminal to the GUARD output on the electrometer. Use the electrometer in FAST mode for ohms measurement.

Model 6105 Resistivity Chamber

Description:

The Model 6105 is a guarded test fixture for measurement of surface and volume resistivities. The chamber is designed in accordance with ASTM Standard Method of Test for Electrical Resistance of Insulating Materials, D257-66. The 6105 can be used in conjunction with an electrometer and voltage supply.

Applications:

Resistivity can be determined by measuring the current through a sample with a known voltage impressed. The measurement can be made most conveniently when a set of electrodes are used which can be calibrated in terms of surface or volume resistivity. The Keithley Model 6105 Resistivity Adapter has been designed for use with a Keithley electrometer and an optional high voltage supply such as the Model 240A.

Model 6106 Electrometer Connection Kit

Description:

The Model 6106 contains a group of the most useful leads and adapters for low current measurements. All components are housed in a rugged carrying case with individual compartments.

Parts List:

Description	Item No.	Keithley Part No.
Cable, 30", UHF to clips	1	19072C
Cable, 24", UHF to UHF	2	18265C
Connector, UHF to UHF	3	CS-5
Adaptor, UHF to BNC	4	CS-115
Adaptor, UHF to BNC	5	CS-172
Adaptor Tee, UHF to UHF	6	CS-171
Adaptor, Binding Post	7	19071B

The two cables (Items 1 and 2) are coaxial shielded leads useful for connections where low noise is essential. The 24" cable (Item 2) can be used to interconnect two instruments having UHF receptacles. The 30" cable (Item 1) can be used to connect to the circuit under test through the use of clip leads. A binding post adapter gives easy access to the electrometer "high" terminal. Two UHF femal couplers (Item 3) permit cables to be connected together. The UHF "tee" connector simplifies galvanometric current measurements when using a current source and electrometer or pico-ammeter. Adapters (Items 4 and 5) are useful for conversion from UHF to BNC terminations.

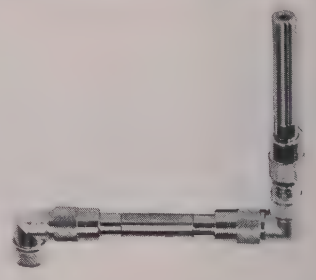
Models 2501, 2503 Static Detector Probes

Description:

The Models 2501 and 2503 are specially designed detectors used to measure static charge on plane surfaces. Either probe must be used with an electrometer such as the 602.

Model 2501:

The 2501 is useful for measurements of charge on flat surfaces. The static head is 3 inches in diameter. Recommended spacing is 3/8" from the surface for 10,000:1 divider ratio. The 2501 is calibrated such that a 1 volt deflection on the electrometer corresponds to 10 kilovolts of static charge.



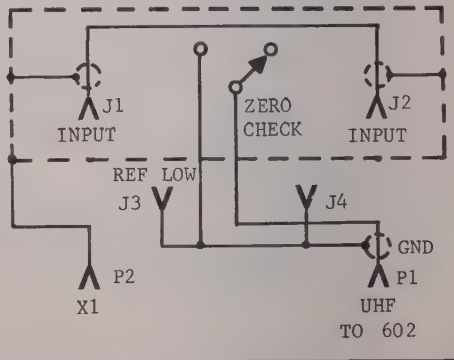
Model 2503:

The 2503 consists of a rigid probe 1/2 inches in diameter. Operation is similar to the use of the 2501 probe.

Model 6107 pH Electrode Adapter

Description:

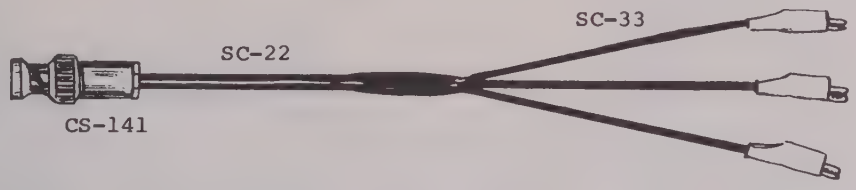
The Model 6107 is a test fixture which simplifies connections to the electrometer when making pH measurements. The adapter can be used with electrodes manufactured by Leeds & Northrup, Coleman and Beckman. The 6107 can be used for guarded measurements as shown in the diagram. A voltage-to-pH conversion chart is supplied with the 6107.



Model 6011 Input Cable

Description: The 6011 is a low-noise triaxial cable, 30" long, terminated by three color-coded alligator clips. This cable mates directly with the triaxial input. The cable is fabricated using a Keithley part no. CS-141 connector and part no. SC-22 low-noise cable. no

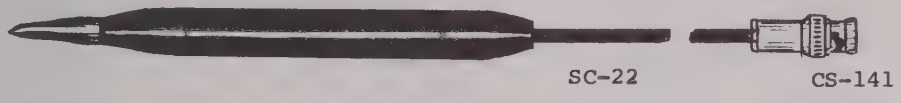
Application: The 6011 may be used for measurements which require a triaxial connection, especially when the input LO is floated above CASE ground. The cable permit full use of the Model 602 capabilities.



Model 6301 Guarded Probe

Description: The 6301 is a guarded triaxial cable, 3 ft. long, terminated by a probe for making point-to-point measurements.

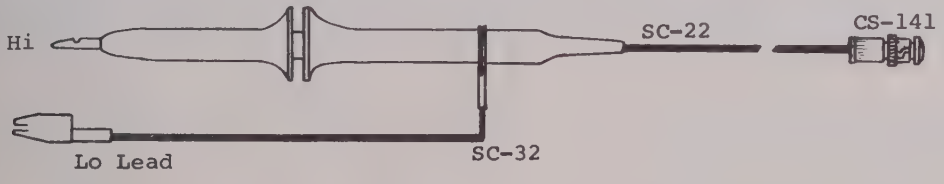
Application: The 6301 may be used for measurements which require a triaxial cable with a guarded probe having an insulation resistance greater than 10^{14} ohms.



Model 1531 Gripping Probe

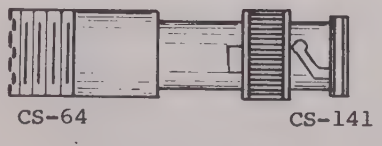
Description: The 1531 is a triaxial cable, 3 ft. long, terminated by a special gripping-type probe. The 1531 insulation resistance is greater than 10^{10} ohms. The probe is rated for off ground measurements up to 500 v

Applicarion: The 1531 may be used for measurements which require a triaxial cable. The probe permits convenient connections to the circuit under test due to the gripping feature.



Model 6012 Triax-to-Coax Adapter

Description: The 6012 is an adapter for mating the triaxial input and UHF (coax) type connectors. This adapter can be used with Models 6101A, 6101B, 6103A, 6102A, etc.

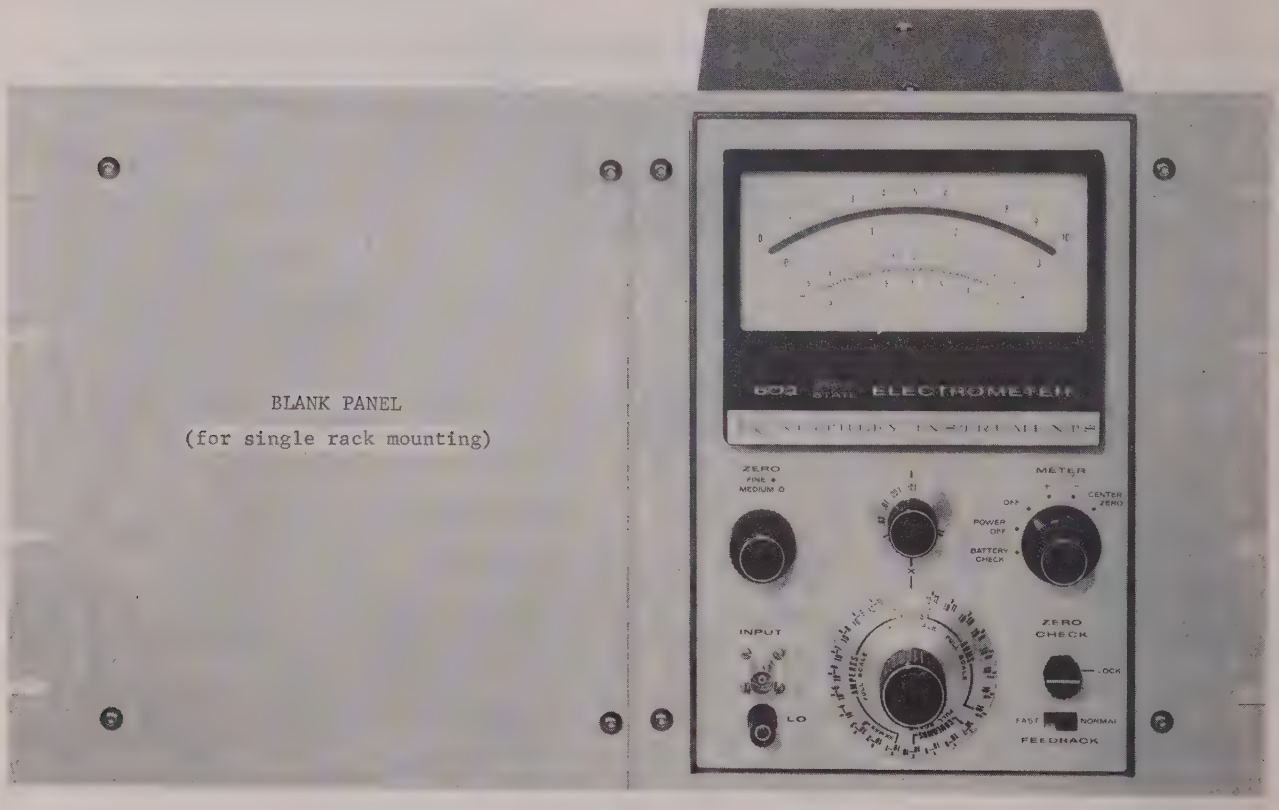


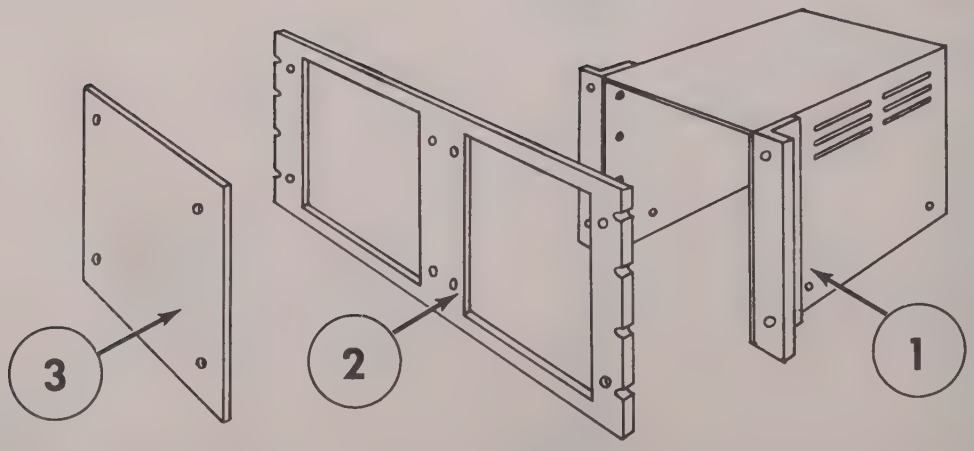
Model 4005 Rack Mounting Kit

Description: The 4005 is a rack mounting kit with overall dimensions of 10-1/2 inches high x 10 inches deep x 19 inches wide (standard EIA rack width). Either one or two instruments can be mounted using this kit. If two instruments are mounted, an additional cover assembly should be purchased (part no. 20018B).

Parts List:

Item	Description	Keithley Part No.
1	Cover Assembly	20018B
2	Rack Panel	19396B
3	Blank Panel	19397B
4	Screw, Hex	#10-3/8
5	Kep Nut	#10

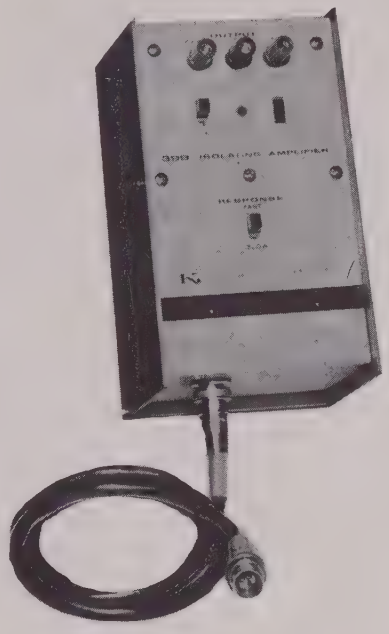




Model 399 Isolating Amplifier

Description: The Model 399 is a unity-gain amplifier that provides input isolation greater than 10^{12} ohms. It is useable for common mode input voltages up to 1500 volts peak, dc or ac.

Application: The 399 can be used for "FIFO" operation where both input and output must be floated. It can also be used to break ground loops within a system. The 399 output will drive recorders up to 1 mA. When used with the Model 602, the electrometer can be floated up to 1500 volts while driving a Model 370 recorder up to 100 volts off ground.

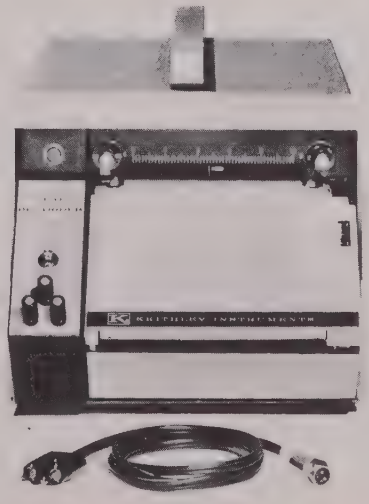


Specifications: (condensed)

GAIN: X1, adjustable ± 3%.
GAIN ACCURACY: ± 0.2% (as set at factory).
GAIN LINEARITY: Within 3 mV for signal levels below 1V.
FREQUENCY RESPONSE: Fast: dc to 100Hz; Slow: dc to 0.3Hz (-3 dB response).
INPUT RESISTANCE: 10^6 ohms.
FULL SCALE INPUT: ± 1 volt with 100% overrange.
MAXIMUM INPUT OVERLOAD: 100 volts.
INPUT ISOLATION: Greater than 10^{12} ohms at 50% relative humidity and 25 C shunted by less than 100 pF.
MAXIMUM COMMON MODE VOLTAGE: 1500 volts peak, dc or ac.
OUTPUT ISOLATION: Greater than 10^8 ohms shunted by less than 0.001 microfarad.
POWER: 105-125 or 210-250 volts (switch selected), 50-60 Hz, 5 watts.

Model 370

Description: The 370 is a compact, paper chart recorder which is compatible with most Keithley instruments having a 1 mA output.



Applications: The 370 can be used directly with the Model 602 up to 500 volts off ground. The Model 3701 cable supplied can be used for convenient connections to the instrument.

SECTION 5. SERVICING

5-1. GENERAL. Section 5 contains the maintenance and troubleshooting procedures for the Model 602 Electrometer. Follow these procedures as closely as possible to maintain the performance of the instrument.

5-2. SERVICING SCHEDULE. Periodically check the condition of the batteries, using the convenient battery check as described in paragraph 2-2. Except for battery replacement, the Model 602 requires no periodic maintenance beyond the normal care required of high-quality electronic equipment. The value of the high-megohm resistors, R110, R111 and R112 should be checked approximately every six months for specified accuracy.

5-3. PARTS REPLACEMENT.

a. The Replaceable Parts List in Section 7 describes the electrical components of the Electrometer. Replace components only as necessary. Use only reliable replacements which meet the specifications.

b. The MOS FET input transistors, Q101 and Q102, are specially selected and matched; order only as a plug-in unit, part number 23733A, from Keithley Instruments.

5-4. TROUBLESHOOTING.

a. The procedures which follow give instructions for repairing troubles which might occur in the Model 602. Use the procedures outlined and use only specified replacement parts. Table 5-1 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, contact Keithley Instruments, Inc., or its representative.

b. Table 5-2 contains the more common troubles which might occur. If the repairs indicated in the table do not clear up the trouble, find the difficulty through a circuit-by-circuit check, such as given in paragraph 5-5. Refer to circuit description to find the more critical components and to determine their function in the circuit. The complete circuit schematic, 21174E, is in Section 7.

5-5. PROCEDURES TO GUIDE TROUBLESHOOTING.

a. If the instrument will not operate, check the condition of the batteries. Then check the OUTPUT Switch. This switch should be in the 1V Position with no load. If these are found satisfactory, use the following procedures to isolate the trouble.

TABLE 5-1.

Test Equipment

Instrument Type	Specification	Manufacturer	Model No.
Digital Voltmeter	1μV to 1000V	Keithley	160
Differential Voltmeter	100mV-500V	Keithley	662
Microvolt Ammeter	5μV-1000V	Keithley	153
RMS Voltmeter	-	Hewlett-Packard	3400A
Nanovolt Source	10^{-9} to 1V	Keithley	260
Voltage Supply	0-1000V	"	241
AC VTVM	-	Hewlett-Packard	400
Picoampere Source	10^{-14}A-10^{-4}A	Keithley	261
Megohmmeter	10^{7}-$10^{13}\Omega$	"	500
Megohm Bridge	10^{5}-$10^{15}\Omega$	"	515A
Resistance Standards	10^{8} to $10^{13}\Omega$	"	5155
Oscilloscope	-	Tektronix	561A
Function Generator	-	Wavetek	102
Recorder	1mA full scale	Keithley	370
Voltage Dividers	10:1, 100:1, 1000:1	Keithley	-

TABLE 5-2.
Model 602 Troubleshooting.

Difficulty	Probable Cause	Solution
Excessive zero offset	Input transistors may be defective.	Check Q101 and Q102; replace if faulty.
	Batteries failing	Replace batteries (paragraph 2-2).
Excessive offset current	Excessive temperature fluctuation or defective input transistors.	Check Q101 and Q102; replace if faulty.
	Instrument not used.	Run for seven hours.
Cannot zero meter on any range.	See paragraph 5-5.	See paragraph 5-5c, step 6.
Unable to zero meter on most sensitive range.	Incorrect gate voltages on input transistors.	Check per paragraph 5-5.
Meter will not zero on one Multiplier Switch setting.	Faulty resistor for setting of Multiplier Switch.	Check resistors; replace if faulty.
10^{-10} to 10^{-14} ampere current ranges are out of specification.	Defective high megohm resistors.	Check per paragraph 6-9.

b. The schematic diagram indicates all transistor terminal voltages referenced to either floating ground or output ground; a properly operating Electrometer will have these values ±10%, if operating from fresh batteries. The control settings for these values are the Range Switch at VOLTS, Multiplier Switch at 1, and the meter zeroed. Measurements are with the Model 153.

c. Amplifier.

1. To check the amplifier, disconnect the feedback loop by removing batteries B204, B205, B206 and B207. This allows each stage of the amplifier to be individually checked. It also eliminates the possibility of applying excessive voltage to the input transistors, causing serious damage.

2. Connect the Model 153 between the drains of Q101 and Q102. Adjust the COARSE and MEDIUM ZERO Controls for null. If null cannot be reached, check the COARSE and MEDIUM ZERO Control circuits (resistors R114 to R135), and transistors Q103 and Q104. Check Q103 and Q104 by removing them and adjusting for null again. If null is now reached, replace the transistor pair with a new pair.

3. Check the next stage by connecting the Model 153 across the emitters of Q103 and Q104 and adjusting the COARSE and MEDIUM ZERO Controls for null. If null is not reached, check this stage and the base circuit of the next stage. Check the base circuit by removing transistors Q105 and Q106 and again adjusting for null. If null is now reached, replace the transistor pair with a new pair.

4. Check the next stage by connecting Model 153 across the collectors of Q105 and Q106 and adjusting the COARSE and MEDIUM ZERO Controls for null. If null is not reached, check this stage and check for shorts in the base circuit of Q107 and Q108.

5. Connect Model 153 to the collector of Q109. Adjust the FINE ZERO Control for null. If null is reached, the dc amplifier is operating correctly. If null is not reached, check transistors Q107 through Q110 and diode D101.

6. The feedback loop includes the multiplier resistors, R156 through R164, the recorder output resistors, R167 on 1V position or R187 and R188 on 1 MA position, and the meter. An opening of any of these components prevents zeroing for only that particular multiplier setting.

7. Replace batteries B204 through B207 and troubleshoot the output stages, transistors Q114 and Q115, by making measurements with Model 153 to within ±10% of the specified schematic value.

SECTION 6. CALIBRATION

6-1. GENERAL.

a. The function of the calibration section is to provide a method of checking the Model 602 to make sure that it operates properly and within the specifications given in Table 1 on page ii.

b. The following procedures are recommended for adjusting and calibrating the Model 602. Use the equipment recommended in Table 5-1 or equivalent. If proper facilities are not available or if irremediable trouble is encountered, refer to troubleshooting procedures in Section 5, or contact Keithley Instruments, Inc., or its representatives.

c. If returning the instrument to Keithley Instruments for repair or calibration, use the Repair and Calibration form at the back of this manual. Use of this form will clarify difficulties that may arise and will result in continued good service. When using this form, please detach along the dotted line.

d. The figures at the end of this section show the component layouts for the Model 602. Refer to them for finding desired components for adjusting the instrument. Refer also to the circuit description in section 3 and the schematic diagram at the back of the manual to identify the more critical components. Also, the Replaceable Parts List in section 7 calls out the components and the figure picturing each component.

NOTE

Unless otherwise stated, all the following calibration procedures will be made with the FEEDBACK Switch set to NORMAL and the 1V-1MA Switch set to 1V.

TABLE 6-1.
Model 602 Internal Controls. The Table lists all internal controls and the paragraph describing the adjustment.

Control	Circuit Desig.	Refer to Paragraph
Meter Calibration	R177	6-4.
Center Zero Calibration	R179	6-4.

6-2. CALIBRATION SCHEDULE.

a. Check offset current (paragraph 6-7) at regular intervals to make sure the input transistors are functioning correctly.

b. Verify the value of the high-megohm resistors (paragraph 6-9) approximately every six months.

c. Calibrate the meter zero (paragraph 6-4) about once a year or when components are replaced.

d. Check the Model 602 accuracy (paragraph 6-10) once a year, after the other adjustments, or if improper operation is suspected.

6-3. PRELIMINARY PROCEDURES.

a. Battery Check. Check the condition of the batteries as outlined in paragraph 2-2a and Table 2-2.

b. Zero Balance. Set the Model 602 to the 10 volt range and turn the instrument on. Set the ZERO CHECK Button to Lock.

1. If the unit is operative, the meter should be on scale, + or -. Zero the meter with the COARSE, MEDIUM and FINE Controls. Increase the voltage sensitivity in steps to the 1 millivolt range by advancing the Multiplier Switch to 1, .3, .1, etc. Zero the instrument on each range.

2. If the instrument is inoperative, meter pinned, etc., check error in setup and obvious problems before initiating detailed troubleshooting.

c. Isolation Check. Use a Keithley Model 500 Megohmmeter to check the resistance between the LO and CASE GND Terminals. It should be greater than 10^{10} ohms. Excessive leakage is generally due to:

1. Low resistance between the meter movement and the meter case. (In this case lift the meter from the Model 602 chassis and recheck the resistance).

2. Or, low surface resistance of the LO, X1 OUTPUT and/or OHMS GUARD Binding Posts.

6-4. MECHANICAL METER SET AND METER ZERO CALIBRATION. Zero whenever other adjustments are made.

a. To set the mechanical Zero meter, turn the METER Switch to METER OFF and set the mechanical Zero Meter adjustment for zero meter reading (top-scale zero).

b. To calibrate meter zero:

1. Turn the Model 602 on. Zero the meter on the .001 Multiplier Switch setting. Then set the Multiplier Switch to 1; apply 1 volt ±0.05% with the Keithley Model 260 Nanovolt Source to the Model 602 INPUT Receptacle. Monitor the output with the Keithley Model 160. Adjust the FINE ZERO Control for 1.000 volt at the output. Adjust the Meter Cal Potentiometer, R177 for full scale meter reading.

2. Set the center zero by first zeroing the meter on the .001 Multiplier Switch setting. Then switch to the 1 position. Set the METER Switch to CENTER

ZERO and adjust the CENTER ZERO CAL potentiometer, R179, for exact center-scale meter zero.

6-5. TRACKING CHECK AND 1MA OUTPUT CALIBRATION.

a. Tracking. Set the METER Switch to +, the Multiplier Switch to 1 and apply 1 volt with the Model 260 to the INPUT Receptacle.

1. If the 1 volt range has good accuracy, the meter should indicate full scale. If not, use the .1 or 10 Multiplier Switch settings, whichever has the best full scale accuracy.

2. Check the meter 0-10 scale for no more than 1/2% (1/2 division) tracking error going from zero to full scale in 1/10 of full scale voltage steps.

b. 1MA Output. Load output of the Model 602 with a 1400 ohm resistor.

1. Set the 1V-1MA Switch to 1MA, the Multiplier Switch to 1 and apply 1 volt to INPUT Receptacle with the Model 260.

2. Adjusting the 1MA CAL Control (R187) should vary the output voltage from 1.33 to 1.47 volts, indicating a current variation from 0.95 to 1.05 milliamperes.

3. Depending on the exact value of the 1400 ohm load, the voltage range may be slightly higher or lower than 1.33 to 1.47 volts; for example, 1.34 to 1.48 volts or 1.32 to 1.46 volts. This is satisfactory provided the overall change is at least 140 millivolts and the maximum voltage is near 1.47 volts.

4. Remove the 1400 ohm load and set the 1V-1MA Switch to 1V when completed.

6-6. NOISE CHECK.

a. Zero check the unit and connect the output to a Hewlett-Packard Model 3400A RMS Voltmeter.

1. Set the METER Switch to CENTER ZERO and zero the Model 602 on the 1 millivolt range.

2. The Meter noise must be less than 50 microvolts peak-to-peak.

3. The Output noise must be less than 30 millivolts rms.

b. Switch the Model 602 to the 300 millivolt range. Output noise must be less than 5 millivolts rms.

c. Typical rms output noise is approximately 20 millivolts on the 1 millivolt range and 1 to 2 millivolts on the 300 millivolt range.

6-7. OFFSET CURRENT CHECK. Check offset current whenever excessive noise or drift is suspected. To read the offset current of the Model 602, set the front panel controls to:

ZERO CHECK Button	LOCK
Multiplier Switch	.003
Range Switch	10^{-11} AMPERES
FEEDBACK Switch	FAST
METER Switch	+

Cap the INPUT Receptacle and unlock the ZERO CHECK Button. The offset current indicated on the meter should be less than 5×10^{-15} ampere. (This is less than 20% of full scale). If this is exceeded, check the battery condition and the input transistor, Q101. If the instrument has not been used for a long time, allow it to run 7 hours before checking the offset current.

6-8. DRIFT CHECK.

a. Set the front panel controls to:

ZERO CHECK Button	LOCK
Multiplier Switch	.01
Range Switch	VOLTS
FEEDBACK Switch	NORMAL
METER Switch	+

Set the OUTPUT Switch on the back panel to 1MA.

b. Connect Model 602 to the Model 370 Recorder. Adjust Recorder sensitivity control completely clockwise (maximum sensitivity) and the 1MA CAL Control of Model 602 for full recorder deflection. Make sure Model 602 chassis cover is attached with at least two screws.

c. Make two drift runs with the Model 602 to determine time and temperature stability individually. For each run allow the Electrometer to warm up for 1/2 hour. A zero drift of less than 2 millivolts after the first half hour is indicative of a satisfactory temperature coefficient. After the first half hour the time stability should be less than 1 millivolt per 24 hours. The offset due to temperature should be less than 150 microvolts per ^{o}C.

d. If the instrument does not meet the zero drift specification, check the batteries. If the batteries are satisfactory and the instrument still does not meet the zero drift specification, the input transistors are faulty.

NOTE

If new batteries have been installed, the Model 602 zero drift will be exceeded for at least 24 hours. Age the unit for 24 hours to enable the battery terminal voltages to stabilize.

6-9. HIGH-MEGOHM RESISTOR VERIFICATION.

a. About every six months it is necessary to check the value of the high-megohm resistors, R110 to R112, on the Range Switch. The instrument should be within its rated accuracy for two or three years from the time it leaves the factory. After this, some of the resistors may drift out of tolerance and should be replaced. Faulty high-megohm resistors will affect the accuracies of measurements for the 10^{-9} to 10^{-11} AMPERES and the 10^{8} to 10^{12} OHMS settings of the Range Switch.

b. To check these resistors, it is necessary to use a bridge capable of better than 1% accuracy up to 10^{11} ohms such as the Keithley Instruments Model 515 Megohm Bridge. If such equipment is not available, two procedures are recommended to check out the resistors:

1. Return the complete instrument to the factory for resistor calibration.

2. Replace the high-megohm resistors periodically with a certified set from Keithley Instruments to assure absolute calibration accuracy.

6-10. ACCURACY CHECK.

a. Checking the accuracy is the quickest way to spot faulty Model 602 operation. Perform the check about once a year, if components are replaced, or if other adjustments are made. If accuracy is verified over all ranges, the Model 602 should be able to meet all specifications. If the accuracy must be checked often, check the stability.

b. Voltage. Connect the Model 602 input to the Model 241 and monitor the output with the Model 160 DVM. First, set the Model 602 for the 10-volt range. Increase the input voltage in 1-volt steps from 0 to 10 volts. The Model 602 should indicate the input voltage to ±1% of full scale. Perform the same operation in the 3-volt range. Connect the Model 602 to the Model 260. Check the other voltage ranges for accuracy of ±1% of full scale. Make sure the OUTPUT Switch is in the 1V position for the 1, 3 and 10 volt ranges (see note of paragraph 2-2g).

c. Current. Connect the Model 602 to the Model 261 with the Model 2611 and monitor the output with the Model 160 DVM. Check the full-scale accuracy of all the current positions on the Range Switch. For the 10^{-6} to 10^{-11} ampere ranges, set the FEEDBACK Switch to FAST and the Multiplier Switch to 1. The Model 602 should indicate the input current to ±2% of full scale to 0.3×10^{-11} ampere ranges. ±4% of full scale from 3×10^{-12} to 10^{-14} ampere ranges. For the ranges above 10^{-5} ampere, construct a current source whose output is ±0.25%. Set the Model 602 FEEDBACK Switch to NORMAL and the Multiplier Switch to .01 when calibrating these ranges.

NOTE

For 10^{-1} ampere through 10^{-5} ampere ranges, a larger Multiplier Switch setting will result in inaccuracies due to loading of the current source; hence the .01 Multiplier Switch setting must be used. The appropriate current source is two decades less than range setting; that is, on the 10^{-1} ampere range use 10^{-3} ampere source, etc.

d. Resistance. Connect the high side of the Model 5155 Resistor to the center terminal of the INPUT Receptacle and the low side to LO. Check the full scale accuracy of all ohm positions on the Range Switch by measuring the voltage drop of the known current across the known sample with the Model 602. The test current applied is the reciprocal of the OHMS Range Setting. Check the 10^{5} through 10^{8} ohm ranges for an accuracy of ±3% of full scale by using the resistance measurement method as described in paragraph 2-6b (FEEDBACK Switch in NORMAL). Check the 10^{9} through 10^{12} ohm ranges for an accuracy of ±5% of full scale by employing the resistance measurement method as described in paragraph 2-6c (FEEDBACK Switch in FAST).

TABLE 6-2.
Coulomb Ranges Accuracy Check. The Table gives the Multiplier Switch setting, the coulomb range checked and the rise time for each coulomb range.

Multiplier Switch Setting	Coulombs Range	Rise Time, Zero to Full Scale (seconds)
.01	10^{-7}	10
.1	10^{-8}	10
1	10^{-9}	10
10	10^{-10}	10

e. Charge. To check the Model 602 as a charge amplifier, set the FEEDBACK Switch to FAST. Apply 10 volts from the Keithley Model 241 Voltage Supply through a Keithley Model 5155 10^{11} ohm standard to the Model 602 input. Set the Multiplier Switch to the settings given in Table 6-2. Use a stop watch or a Tektronix Model 561A Oscilloscope to time the rise to full scale deflection. Check each range to ±5%.

6-11. UNITY GAIN CHECK.

a. Zero check the Model 602 and set the instrument to the 10 volt range. Connect the Model 241 Voltage Supply to the Model 602 INPUT Receptacle and to the Model 662 Differential Voltmeter High terminal. Connect the Electrometer X1 OUTPUT Terminal to the low terminal of the Model 662. Set the Model 662 dial to 0 and the Null Switch to 1 millivolt. The Model 662 should indicate at or near zero.

NOTE

A large transient is generated when the Model 241 is switched from Standby to Output. To prevent false indication, set the Model 241 to Output and use voltage dial (0 or 10 volts) when making this check.

b. Set the Model 241 to zero volts, release the Electrometer ZERO CHECK Button and note that the Model 662 null remains the same.

1. Apply +10 volts to the Model 602 input with the Voltage Supply. The Differential Voltmeter null indication should not change more than 0.1 millivolt, indicating a unity gain within 10 ppm.

2. Repeat the test of subparagraph 1 above using -10 volts.

6-12. FREQUENCY RESPONSE CHECK.

a. Zero check the unit. Connect a Wavetek Model 102 Function Generator through a 1000:1 divider to the

Model 602 input and connect the Electrometer output to a Hewlett-Packard Model 400 AC VTVM. Set the Electrometer FEEDBACK Switch to NORMAL.

NOTE

If other than a constant amplitude signal generator (Wavetek) is used, it will be necessary to monitor the output of the signal generator with another VTVM in order to maintain the same signal level at various frequencies specified.

b. Zero the Model 602 on the 1 millivolt range.

1. Set the Signal Generator to 20 Hz at minimum output. Release the Electrometer ZERO CHECK Button and increase the Generator output to obtain 2 volts rms at the Model 602 output.

2. Set the Generator to 100 Hz. The Electrometer output voltage must be within ±3 dB of the 20 Hz 2 volt rms output.

c. Zero the Model 602 on the 1 volt range and change the divider to 100:1.

1. Set the Generator to 100 Hz for minimum output. Release the Electrometer ZERO CHECK Button and increase the Generator output to obtain 0.1 volt rms at the Model 602 output.

2. Set the Generator to 40 kHz. The Electrometer output must be within ±3 dB of the 100 Hz 0.1 volt rms output.

d. Zero the Model 602 on the 1 volt range and change the divider to 10:1.

1. Set the Generator to 100 Hz and for minimum output. Release the ZERO CHECK Button and increase the Generator output to obtain 2 volts rms at the Electrometer output.

2. Set the Generator to 3 kHz. The Model 602 output must be within ±3 dB of the 100 Hz 2 volt rms output.

6-13. COMMON MODE REJECTION CHECK.

a. Cap the INPUT Receptacle and set the Model 602 front panel controls as follows:

ZERO CHECK Button	LOCK
Multiplier Switch	1
Range Switch	10^{-10} AMPERES
FEEDBACK Switch	NORMAL
METER Switch	OFF

b. Connect the Model 102 Generator between the Electrometer LO and CASE GND Terminals and connect the Model 561A Oscilloscope to the Model 602 OUTPUT Receptacle.

c. Apply a 35 volt peak-to-peak, 60 Hz signal to the Electrometer input. The output should be less than 35 mV peak-to-peak.

10 Gn

10 " 100M 100K
10,000,000,000

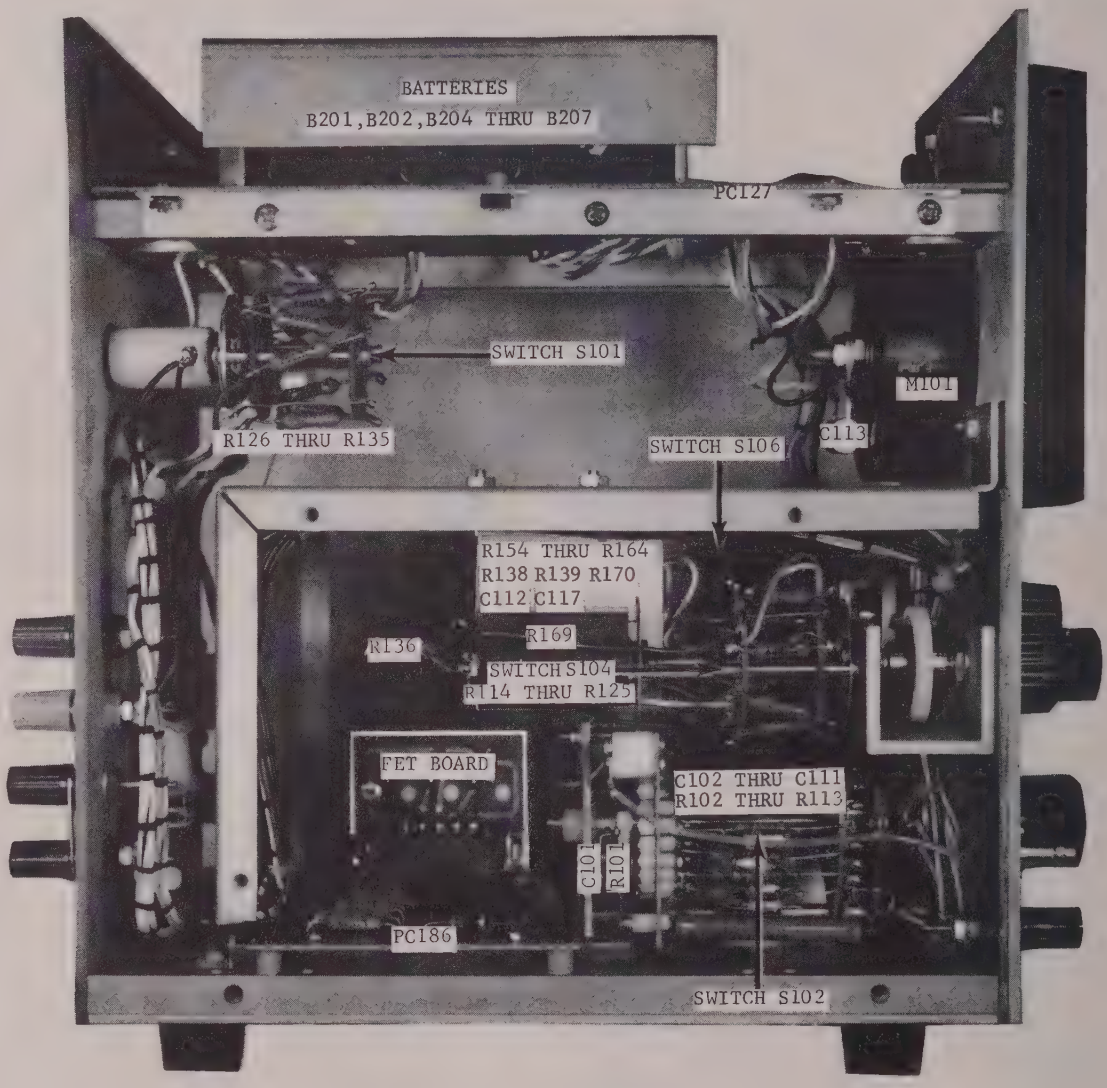


FIGURE 13. Chassis, Side View.

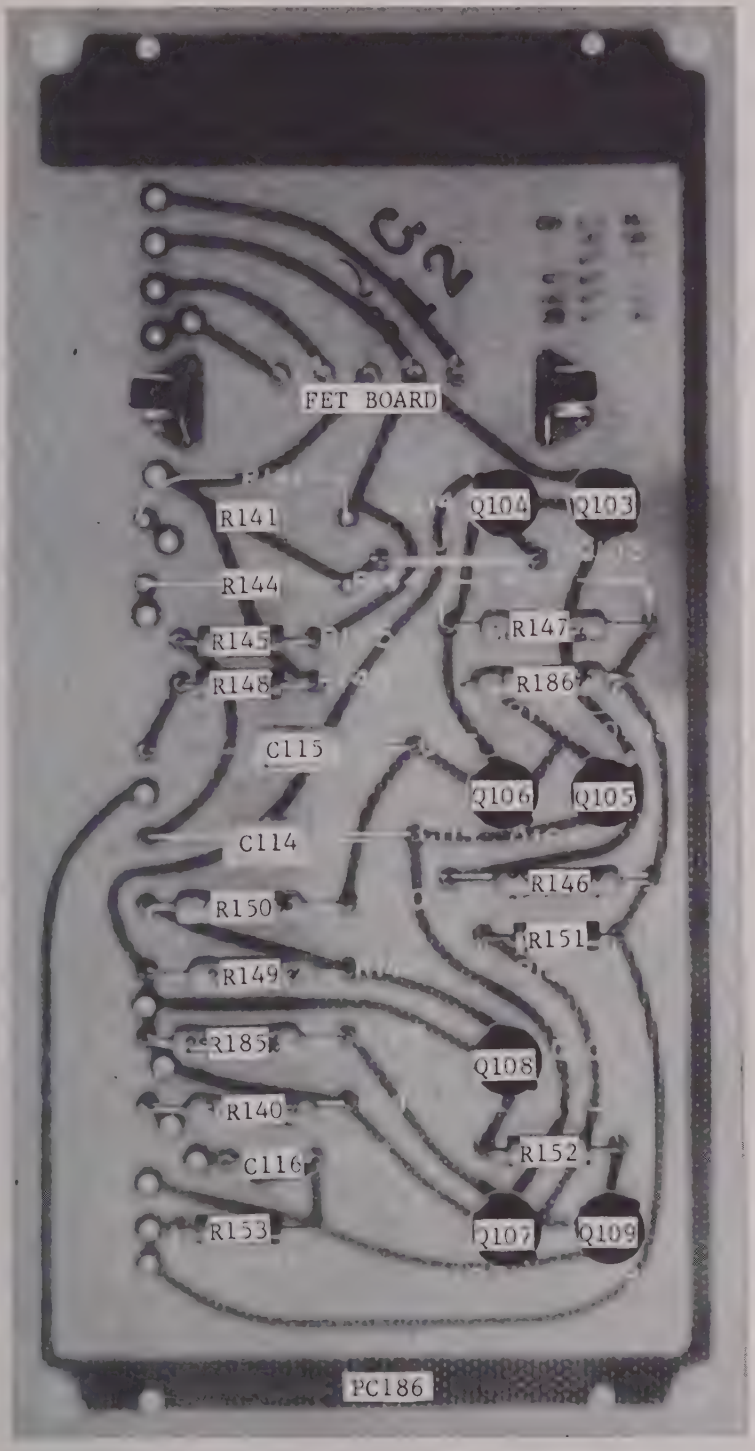


FIGURE 14. Component Layout, PC186.

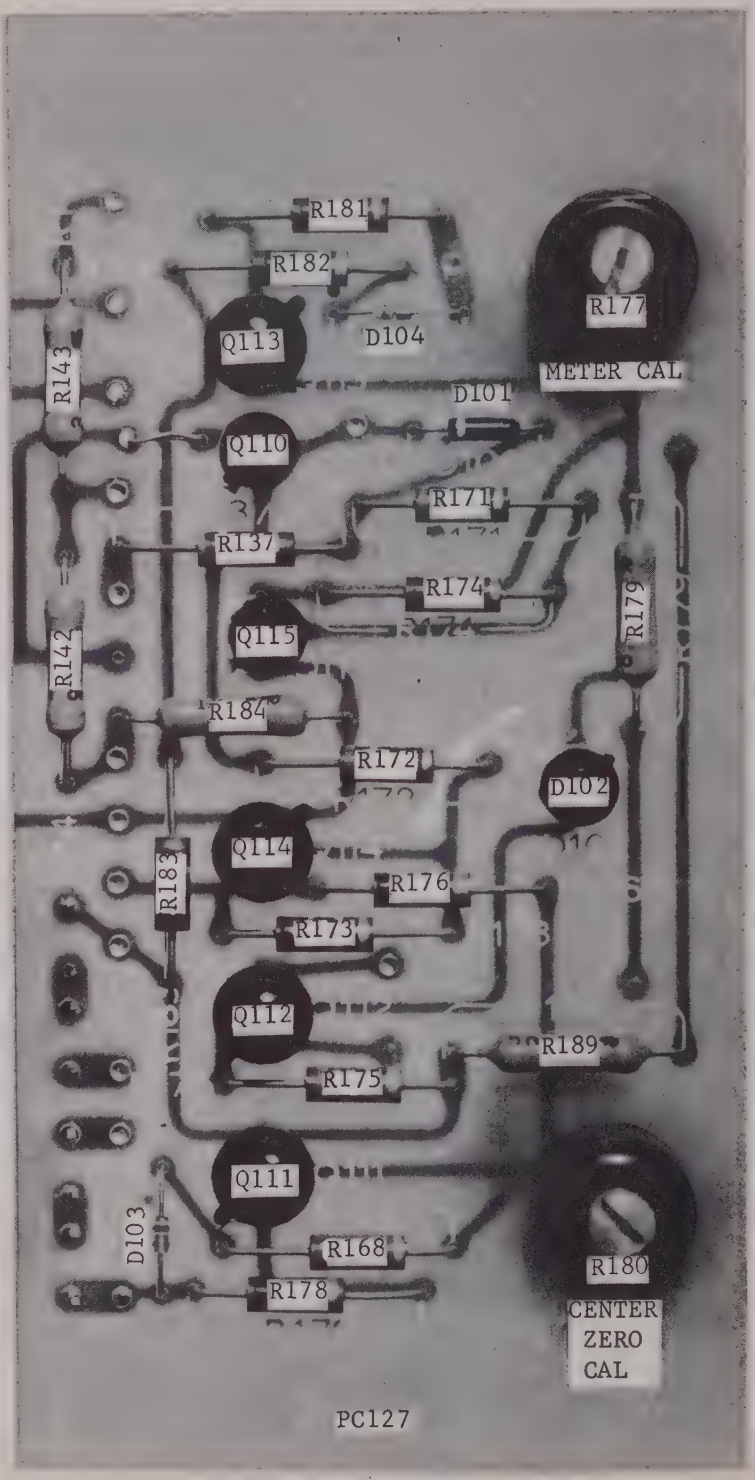


FIGURE 15. Component Layout, PC127.

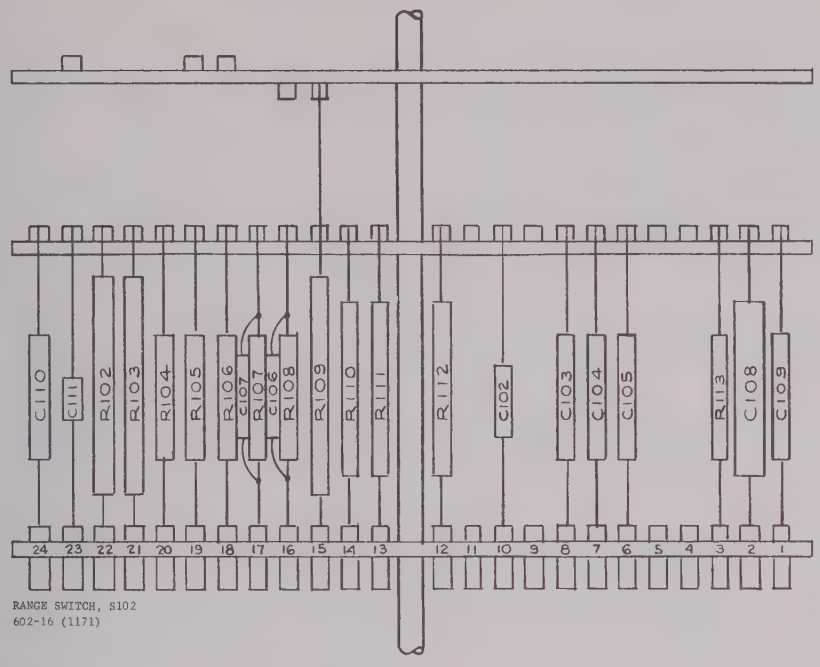


FIGURE 16. Component Locations, RANGE Switch, S102.

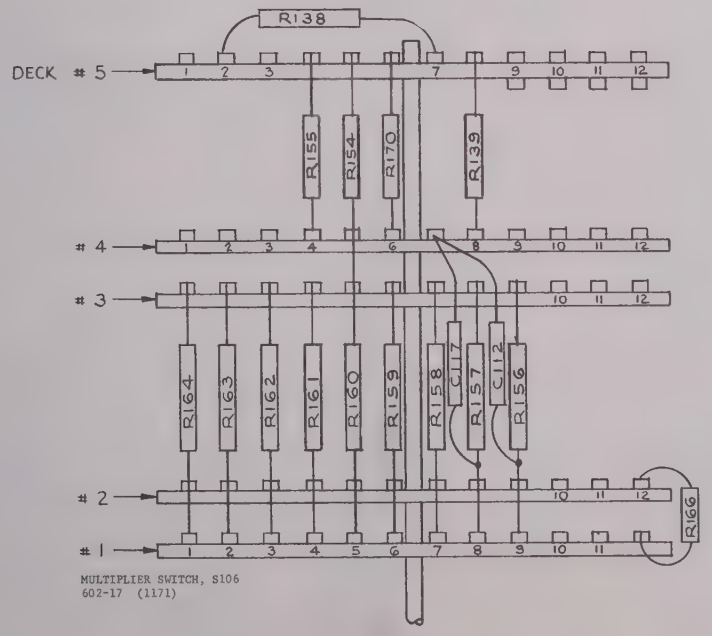


FIGURE 17. Component Locations, MULTIPLIER Switch, S106.

SECTION 7. REPLACEABLE PARTS

7-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 602 (and its accessories). The List gives the circuit designation, the part description, a suggested manufacturer, the manufacturer's part number and the Keithley Part Number. The last column indicates the figure picturing the part. The name and address of the manufacturers listed in the "Mfg. Code" column are in Table 7-1.

7-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those coded for Keithley manufacture (80164) must be ordered through Keithley Instruments, Inc., or its representatives. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

b. Order parts through your nearest Keithley representative or the Sales Service Department, Keithley Instruments, Inc.

TABLE 7-1. Abbreviations and Symbols.

A	ampere	GCb	Glass enclosed carbon	Ω	ohm
CerD	Ceramic, disc	k	kilo (10^3)	p	pico (10^{-12})
Comp	Composition			Poly	Polystyrene
		M or meg	mega (10^6) or megohms		
DCb	Deposited Carbon	Mfg.	Manufacturer	Ref.	Reference
		MtF	Metal Film	Req'd.	required
EAl	Electrolytic, Aluminum	My	Mylar		
ETB	Electrolytic, tubular			V	volt
		μ	micro (10^{-6})		
F	farad			W	watt
Fig.	Figure	No.	number	WW	Wirewound
				WWVar	Wirewound Variable

MODEL 602 REPLACEABLE PARTS LIST.
(Refer to Schematic Diagram 21174E for circuit designations.)

BATTERIES

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
B201	9V zinc carbon battery	09823	2N6	BA-17	13
B202	9V zine carbon battery	09823	2N6	BA-17	13
B203	1.34V battery	37942	PX-1	BA-24	13
B204	9V zinc carbon battery	09823	2N6	BA-17	13
B205	9V zinc carbon battery	09823	2N6	BA-17	13
B206	9V zinc carbon battery	09823	2N6	BA-17	13
B207	9V zinc carbon battery	09823	2N6	BA-17	13

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C101	150 pF	600 V	CerD	72982	SM1A	C22-150P	13
C102	5 pF	200 V	Poly	83125	E1013-1	C31-5P	16
C103	10 pF	500 V	Poly	71590	CPR-10J	C138-10P	16
C104	22 pF	500 V	Poly	71590	CPR-22J	C138-22P	16
C105	47 pF	500 V	Poly	71590	CPR-47J	C138-47P	16
C106	100 pF	200 V	Poly	84171	2PJ-101G	C108-100P	16
C107	.001 μF	200 V	Poly	84171	2PJ-102G	C108-.001M	16
C108	.1 μF	200 V	Poly	84171	2PJ-104G	C108-.1M	16
C109	.01 μF	200 V	Poly	84171	2PJ-103G	C108-.01M	16
C110	.001 μF	200 V	Poly	84171	2PJ-102G	C108-.001M	16

CAPACITORS Continued

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C111	100 pF	200 V	Poly	84171	2PJ-101G	C108-100P	16
C112	.0047 μF	600 V	CerD	72982	ED-.0047	C22-.0047M	13
C113	125 μF	15 V	ETB	73445	C 426	C3-125M	13
C114	.033 μF	200 V	My	13050	SM1A	C143-.033M	14
C115	.033 μF	200 V	My	13050	SM1A	C143-.033M	14
C116	150 pF	600 V	CerD	72982	ED-150	C22-150P	14
C117	.001 μF	600 V	CerD	72982	ED-.001	C22-.001M	13

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Silicon	1N645	01295	RF-14	15
D102	Silicon	2N3565	07263	TG-39	15
D103	Silicon	1N914	01295	RF-28	15
D104	Silicon	1N914	01295	RF-28	15

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
21850B	MOS FET Input Plug-in Card	80164	23733A	13
---	Battery Snap, 6 req'd (Mfg. No. 5D)	71785	BH-6	
---	Battery holder	80164	20944A	
J108	Receptacle, triaxial, INPUT (Mfg. No. 33050-1)	95712	CS-181	2
---	Plug, triaxial, mate of J101 (Mfg. No. 30197-1)	95712	CS-141	
---	Cap, INPUT Receptacle (Mfg. No. 31-007	02660	CAP-18	
J102	Binding Post, LO (Mfg. No. DF21B)	58474	BP-11B	2
J103	Receptacle, Microphone, OUTPUT (Mfg. No. 80-PC2F)	02660	CS-32	3
---	(F)Plug, Microphone, mate of J103 (Mfg. No. 80-MC2M)	02660	CS-33	
J104	Binding Post, CASE GROUND (Mfg. No. DF21GRN)	58474	BP-11GRN	3
J105	Binding Post, X1 OUTPUT (Mfg. No. DF21R)	58474	BP-11R	3
J106	Binding Post, LO (Mfg. No. DF21B)	58474	BP-11B	3
J107	Binding Post, GUARD (Mfg. No. DF21BLU)	58474	BP-11BLU	3
M101	Meter	80164	ME-81	13
S101	Rotary Switch less components, COARSE ZERO	80164	SW-166	2
---	Rotary Switch with components	80164	20924B	
S102	Rotary Switch less components, RANGE	80164	SW-204	2,16
---	Rotary Switch with components	80164	20922B	
---	Dial Assembly, Range Switch	80164	18039A	
S103	Push Button Switch, ZERO CHECK	80164	14376A	2
S104	Rotary Switch less components, MEDIUM ZERO	80164	SW-209	2
---	Rotary Switch with components	80164	20926B	
---	Knob Assembly	80164	18039A	
S105	Slide Switch, FEEDBACK	80164	19089A	2
R169	FINE ZERO Control	12697	RP42-10K	2
---	Knob Assembly, Fine Zero Control	80164	16995A	

(F) Furnished Accessory.

MISCELLANEOUS PARTS (Cont'd).

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
S106	Rotary Switch less components, Multiplier	80164	SW-205	2,17
---	Rotary Switch with components	80164	20929B	
---	Dial Assembly, Multiplier Switch	80164	19223A	
S107	Rotary Switch less components, METER	80164	SW-320	2
---	Rotary Switch with components	80164	24278B	
S108	Slide Switch, OUTPUT	80164	SW-45	3

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	KEITHLEY Part No.	Fig. Ref.
R101	10 MΩ	10%, 1/2 W	Comp	01121	EB2	R1-10M	13
R102	10 Ω	1%, 10 W	WW	91637	RS-10	R34-10	16
R103	100 Ω	1%, 10 W	WW	91637	RS-10	R34-100	16
R104	1 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-1K	16
R105	10 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-10K	16
R106	100 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-100K	16
R107	1 MΩ	1%, 1/2 W	DCb	07716	DCC	R12-1M	16
R108	10 MΩ	1%, 1/2 W	DCb	07716	DCC	R12-10M	16
R109	100 MΩ	1%, 2 W	DCb	91637	DC-2	R14-100M	16
R110	10^9 Ω	+3-0%,1/R W	GCb	63060	RX-1	R20-10^9	16
R111	10^{10} Ω	+3-0%, 1/R W	GCb	63060	RX-1	R20-10^{10}	16
R112	10^{11} Ω	+ -0%, 1/R W	GCb	63060	RX-1	R20-10^{11}	16
R113	134 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-134K	16
R114	68.1 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-68.1K	13
R115	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R116	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R117	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R118	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R119	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R120	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R121	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R122	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R123	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R124	806 Ω	1%, 1/2 W	DCb	07716	DCC	R12-806	13
R125	68.1 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-68.1K	13
R126	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R127	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R128	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R129	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R130	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R131	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R132	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R133	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R134	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R135	249 Ω	1%, 1/2 W	DCb	07716	DCC	R12-249	13
R136	40.2 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-40.2K	13
R137	39 k Ω	10%, 1/2 W	Comp	01121	EB	R1-39K	--
R138	20 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-20K	13
R139	20 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-20K	13
R140	34.8 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-34.8K	14

RESISTORS (Cont'd).

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R141	200 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-200K	14
R142	9 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-9K	15
R143	3.4 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-3.4K	15
R144	200 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-200K	14
R145	2.2 kΩ	10%, 1/2 W	Comp	01121	EB	R1-2.2K	14
R146	36.5 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-36.5K	14
R147	36.5 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-36.5K	14
R148	2.2 kΩ	10%, 1/2 W	Comp	01121	EB	R1-2.2K	14
R149	21.5 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-21.5K	14
R150	7.15 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-7.15K	14
R151	270 kΩ	10%, 1/2 W	Comp	01121	EB	R1-270K	14
R152	4.7 kΩ	10%, 1/2 W	Comp	01121	EB	R1-4.7K	14
R153	100 kΩ	10%, 1/2 W	Comp	01121	EB	R1-100K	14
R154	10 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-10K	13,17
R155	1.5 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-1.5K	13,17
R156	9.1 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-9.1K	13,17
R157	2.73 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-2.73K	13,17
R158	910 Ω	0.5%, 1/2 W	MtF	07716	CEC	R61-910	13,17
R159	273 Ω	0.5%, 1/2 W	MtF	07716	CEC	R61-273	13,17
R160	91 Ω	0.5%, 1/2 W	MtF	07716	CEC	R61-91	13,17
R161	27.3 Ω	0.5%, 1/2 W	MtF	07716	CEC	R61-27.3	13,17
R162	9.1 Ω	0.5%, 1/4 W	WW	01686	TS-1W	R123-9.1	13,17
R163	2.73 Ω	0.5%, 1/4 W	WW	01686	TS-1W	R123-2.73	13,17
R164	.91 Ω	0.5%, 1/4 W	WW	01686	TS-1W	R123-.91	13,17
R165	Not Used						--
R166	10 Ω	10%, 1/2 W	Comp	44655	RC07	R76-10	--
R167	910 Ω	0.5%, 1/2 W	MtF	07716	CEC	R61-910	--
R168	10 kΩ	10%, 1/2 W	Comp	01121	EB	R1-10K	15
R169	10 kΩ	5%, 2 W	WWVar	12697	62JA	RP42-10K	2
R170	10 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-10K	17
R171	6.8 kΩ	10%, 1/2 W	Comp	01121	EB	R1-6.8K	15
R172	6.8 kΩ	10%, 1/2 W	Comp	01121	EB	R1-6.8K	15
R173	180 kΩ	10%, 1/2 W	Comp	01121	EB	R1-180K	15
R174	180 kΩ	10%, 1/2 W	Comp	01121	EB	R1-180K	15
R175	82 kΩ	10%, 1/2 W	Comp	01121	EB	R1-82K	15
R176	120 kΩ	10%, 1/2 W	Comp	01121	EB	R1-120K	15
R177	2 kΩ	10%, 5 W	WWVar	71450	AW	RP34-2K	15
R178	120 Ω	10%, 1/2 W	Comp	01121	EB	R1-120	15
R179	8.06 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-8.06K	15
R180	15 kΩ	10%, 3 W	WWVar	71450	AW	RP3-15K	15
R181	120 Ω	10%, 1/2 W	Comp	01121	EB	R1-120	15
R182	10 kΩ	10%, 1/2 W	Comp	01121	EB	R1-10K	15
R183	120 kΩ	10%, 1/2 W	Comp	01121	EB	R1-120K	15
R184	1 kΩ	0.5%, 1/2 W	MtF	07716	CEC	R61-1K	15
R185	28.7 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-28.7K	14
R186	11.8 kΩ	1%, 1/2 W	MtF	07716	CEC	R94-11.8K	14
R187	20 kΩ	10%, 5 W	WWVar	71450	AW	RP34-20K	--
R188	8.66 kΩ	1%, 1/2 W	DCb	07716	DCC	R12-8.66K	--
R189	500 Ω	1%, 1/2 W	DCb	07716	DCC	R12-500K	15
R190	6.8 kΩ	10%, 1/2 W	Comp	01121	EB	R1-6.8K	--
R191	6.8 kΩ	10%, 1/2 W	Comp	01121	EB	R1-6.8K	--
R192	6.8 kΩ	10%, 1/2 W	Comp	01121	EB	R1-6.8K	--

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q101**		80164		
Q102**		80164		
Q103	2N3903	04713	TG-49	14
Q104	2N3903	04713	TG-49	14
Q105	2N3903	04713	TG-49	14
Q106	2N3903	04713	TG-49	14
Q107	2N3903	04713	TG-49	14
Q108	2N3903	04713	TG-49	14
Q109	2N3905	04713	TG-53	14
Q110	2N3903	04713	TG-49	15
Q111	S17638	07263	TG-33	15
Q112	S17638	07263	TG-33	15
Q113	S17638	07263	TG-33	15
Q114	2N3905	04713	TG-53	15
Q115	2N3903	04713	TG-49	15

** Q101 and Q102 are matched and mounted on a specially built plug-in card with built-in overload protection.

Code List of Suggested Manufacturers (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1).

01121 Allen Bradley Corp.
1201 South 2nd Street
Milwaukee, Wis. 53204

01295 Texas Instruments, Inc.
Semiconductor Components
Division
13500 N. Central Expressway
Dallas, Texas 75231

01686 RCL Electronics, Inc.
195 McGregor Street
Manchester, N.H. 03102

02660 Amphenol Corp.
2801 South 25th Avenue
Broadview, Ill. 60153

04713 Motorola Semiconductor
Products, Inc.
5005 E. McDowell Rd.
Phoenix, Arizona 85008

07263 Fairchild Camera & Instru.
Corp.-Semiconductor Div.
313 Frontage Road
Mountain View, Calif.

07716 IRC, Inc.
2850 Mt. Pleasant
Burlington, Iowa 52601

09823 Burgess Battery Co.
Division of Servel, Inc.
Foot of Exchange St.
Freeport, Ill.

12697 Clarostat Mfg. Co., Inc.
Lower Washington St.
Dover, N.H. 03820

13050 Potter Co.
Highway 51 N.
N. Wesson, Miss. 39191

37942 Mallory, P.R. & Co., Inc.
3029 E. Washington St.
Indianapolis, Ind. 46206

44655 Ohmite Mfg. Co.
3601 Howard St.
Skokie, Ill. 60076

58474 Superior Electric Co., The
383 Middle St.
Bristol, Conn. 06012

63060 Victoreen Instrument Co.
5806 Hough Avenue
Cleveland, Ohio 44103

71450 CTS Corp.
1142 W. Beardsley Ave.
Elkhart, Ind.

71590 Centralab Division of
Globe-Union, Inc.
932 E. Keefe Avenue
Milwaukee, Wisconsin 53212

71785 Cinch Mfg. Co. and Howard
B. Jones Division
1026 S. Homan Avenue
Chicago, Ill. 60624

72982 Erie Technological Products,
Inc.
644 W. 12th Street
Erie, Pa. 16512

73445 Amperex Electronic Co., Div.
of North American Philips Co.
Hicksville, N.Y.

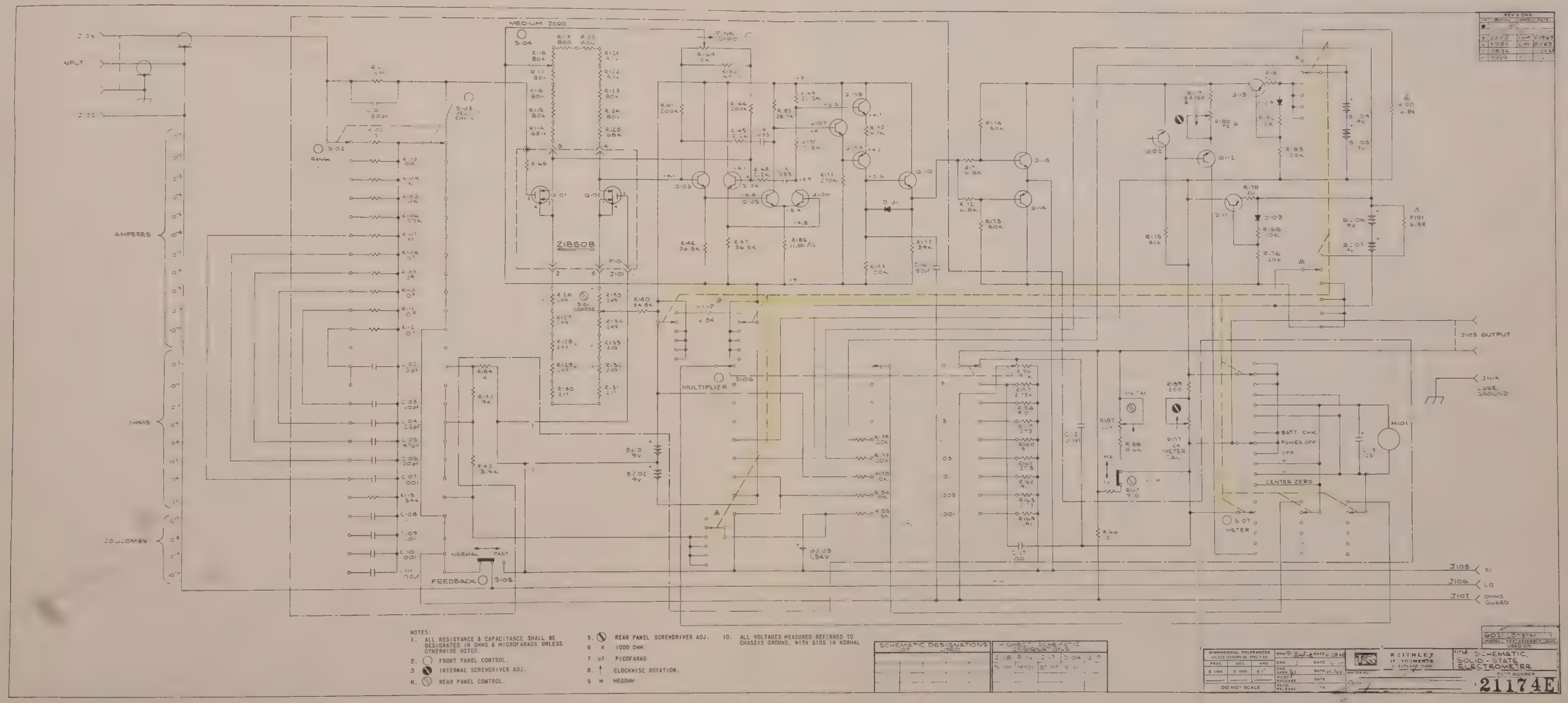
80164 Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139

83125 General Instrument Corp.
Capacitor Division
Orange Street
Darlington, S.C. 29532

84171 Arco Electronics, Inc.
Community Drive
Great Neck, N.Y. 11022

91637 Dale Electronics, Inc.
P.O. Box 609
Columbus, Nebraska 68601

95712 Dage Electric Co., Inc.
Hurricane Road
Franklin, Indiana



NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ◯ FRONT PANEL CONTROL.
3. ⊘ INTERNAL SCREWDRIVER ADJ.
4. ⊘ REAR PANEL CONTROL.
5. ⊘ REAR PANEL SCREWDRIVER ADJ.
6. K 1000 OHM
7. pf PICOFARAD
8. ↑ CLOCKWISE ROTATION.
9. M MEGOHM
10. ALL VOLTAGES MEASURED REFERRED TO CHASSIS GROUND, WITH SIOS IN NORMAL

REPAIR AND CALIBRATION FORM

For repair or calibration, please fill out this form and return it with your instrument to:

Sales Service Department
Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139

R-_____
Do not write in this space.

User's Name _____ Telephone _____ Ext. _____
Company _____ Address _____
Division _____ City _____ State _____ Zip _____
Date _____ Model No. _____ Serial No. _____

1. Reason for Return
   - ☐ Repair and Recalibration
   - ☐ Recalibration only (No report, except as specified in item 4 on reverse)*

   *If repairs are necessary to meet specifications, they will be in addition to the calibration.

2. Calibration Report Desired
   - ☐ Report of Calibration Certified Traceable to N.B.S.
   - ☐ Calibration Report
   - ☐ Certificate of Compliance
   - ☐ None

   (for details, see reverse side of this form)

3. To help repair the instrument, briefly describe the problem: _____

4. Is the problem ☐ Constant ☐ Intermittant
   Under what conditions does the problem occur:
   a) Control setting _____
   b) Approx. Temperature _____ °F
   c) Approx. Temperature variation ± _____ °F
   d) Approx. Humidity (high, medium, low) _____
   e) Line voltage _____
   f) Other (such as line transients, line variations, etc.) _____

5. Please draw a block diagram of the system using the Keithley. List any other pertinent data which can help in the repair. Include charts or other data if available.
   Signal Source _____
   Source Impedance _____
   Readout Device:
   - ☐ Recorder
   - ☐ Oscilloscope
   - ☐ Other
   - ☐ None

   Lengths & Types of Connecting Cables _____

6. What repairs or modifications have been made on this instrument which are not on file with the Keithley Repair Department? _____

7. Please enclose any other pertinent data and charts which you feel might help the Repair and Calibration Department

_____ Signature _____ Title

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CALIBRATIONS AVAILABLE AT KEITHLEY INSTRUMENTS.

Listed and defined below are the four types of calibrations and their associated report formats which are presently available at Keithley Instruments. They fall into the following categories:

1. Report of Calibration Certified Traceable to the National Bureau of Standards
2. Calibration Report
3. Certificate of Compliance
4. Recalibration

All calibration and certification performed by Keithley Instruments is in accord with MIL-C-45662A.

Prices shown below are in addition to repair charges for any work necessary to place a customer's unit into first class condition prior to the calibration.

1. Report of Calibration Certified Traceable to the National Bureau of Standards.
   This is a completely documented report, including all basic errors or deviations from nominal settings on appropriate ranges, terminals, dials, etc. Work is performed using the primary standards of the company with secondary transfers kept to a minimum. The NBS test numbers for the latest recalibration of the primary standards are furnished.

   By definition, the above is performed in our Standards Laboratory so that random operator induced error is minimized and maximum protection to the equipment used is maintained.

   This type of calibration is not recommended for instruments with a basic inaccuracy of 1% or greater. The precision involved in this report makes it uneconomical for such instruments. The Calibration Report listed below (No. 2) would be better suited in this case.

   As of 11/1/69 the Report of Calibration Certified Traceable to the National Bureau of Standards is available on the following instruments at the prices listed:

Model 140	$275	Model 5155 (Complete Set)	$295
Model 260	$225	Model 5155-10^8	$ 50
Model 261	$375	Model 5155-10^9	$ 50
Model 515	$375	Model 5155-10^{10}	$ 50
Model 630	$275	Model 5155-10^{11}	$ 60
Model 660A	$250	Model 5155-10^{12}	$ 60
Model 662	$275	Model 5155-10^{13}	$ 80

2. Calibration Report.
   This report shows only the cardinal range, terminal, dial, etc. errors as determined by production calibration equipment and personnel. The production equipment is maintained traceable by transfer techniques against the primary standards maintained by the company. We attest to this fact and list basic deviations from nominal but the conditions of calibration are not as precisely controlled as the previous report nor are NBS test numbers supplied.

   This report is available for any instrument in our line. As of November 1, 1969, only the following price has been established for this report:

   Model 261 . . . . . $ 55

   Prices for other units can be estimated upon request.

3. Certificate of Compliance.
   This is merely a restatement of the basic guarantee that the instrument was calibrated on equipment that is maintained by our standards personnel against primary standards. No report is issued.

   This Certificate of Compliance is available at no charge for any instrument with the exception of the Model 261.

   A newly purchased Model 261 or one returned for repair or recalibration is automatically supplied with a Calibration Report (as described in (2) above). The nature of this instrument makes it necessary to complete this report to ascertain specified accuracy. This Calibration Report is forwarded to the customer with the instrument. The $55 charge is incorporated as part of the normal calibration charge of the Model 261.

4. Recalibration.
   This is a recalibration of the instrument according to our factory calibration procedures. The prices for this as of November 1, 1969 are as follows:

   Model 260 . . . . . $ 85 (No report supplied. A Certificate of Compliance can be had at no charge if requested).

   Model 261 . . . . . $ 55 (Calibration Report as described in (2) above is supplied. See (3) for explanation).

   All other instruments are on a time and material basis for the particular unit involved.

www.manualsplus.com
1036237

KEITHLEY INSTRUMENTS, INC.

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TELEX: 98-5469 • CABLE: KEITHLEY